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Explore the UNIVERSE® 2006

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Saturn and its rings • Titan and other moons

The Red Planet: Seeking far horizons

Voyage to Pluto set for launch

Galaxy recipe: gas, dust, and violence

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Saturn and its rings stand among the most spectacular sights in the solar system. Yet it's taken the Cassini and Huygens spacecraft to show how truly special Saturn's entire system is. PAGE 8

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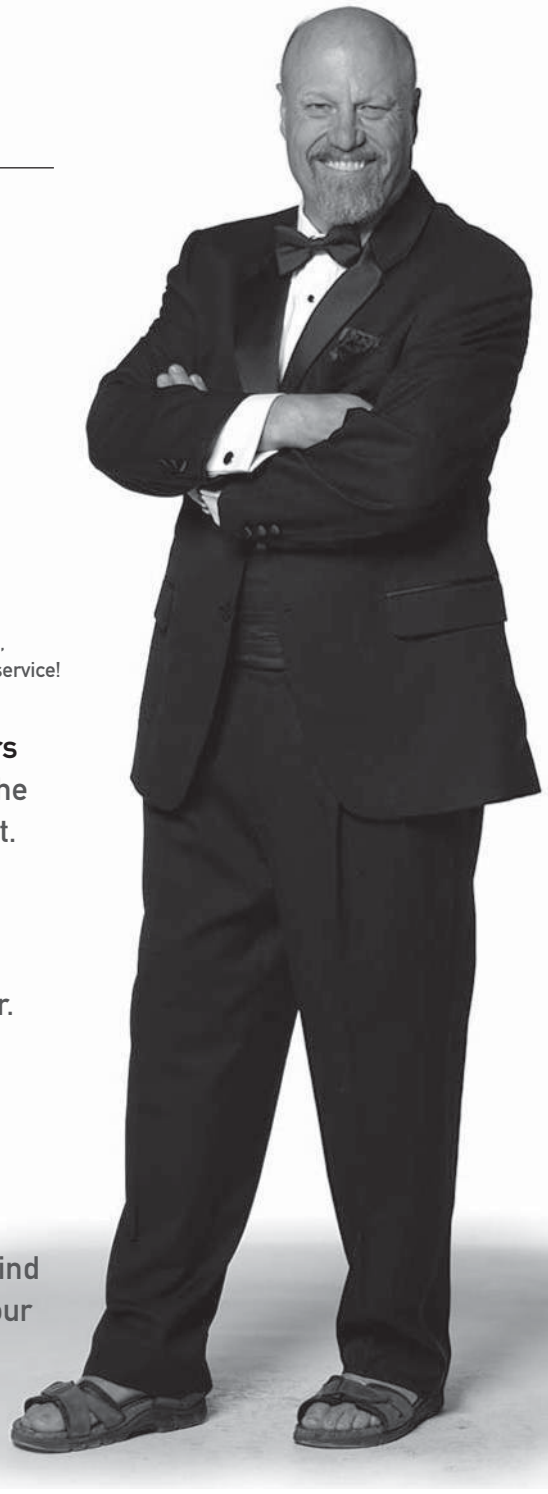

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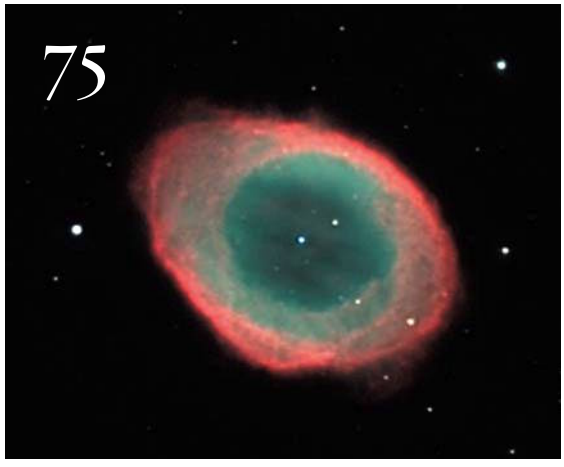

ADAM BLOCK/NOAO/AURA/NSF

ON THE COVER

Often the first object many see through a telescope, Saturn displays its rings as never before in this Cassini spacecraft image. This mission is transforming scientists' views of the ringed planet (see page 8).

NASA/JPL/SSI; INSET: JASON WARE

JASON WARE

at the eyepiece

Big times in the planet world

ASTRONOMY: WILLIAM ZUBACK

Planetary exploration blossomed in the late 1970s and 1980s, when the Voyager spacecraft gave us a "grand tour" of the solar system. Now, we are in a mini-boom of returning to the planets. Senior Editor Robert Burnham has been following the recent exploration of Mars like few other journalists. In "The Red Planet: Seeking far

horizons" (page 16), Burnham delivers a spectacular summary of what spacecraft continue to do there.

Two rovers on the ground and three orbiters overhead are firing Mars data back to Earth every day, while a sixth vehicle, the Mars Reconnaissance Orbiter, stands poised on the launch pad. This fleet is pursuing a goal that NASA describes as "following the water" — a strategy designed to see if Mars has a biosphere, or ever had one in the past. Burnham's story explores the exciting discoveries these spacecraft are making.

New findings are not limited to the Red Planet, however. Just a year into its 4-year mission, the Cassini spacecraft continues to orbit Saturn. Perhaps the mission's most amazing moments so far came when the Huygens probe decoupled from Cassini and dropped onto the surface of Saturn's largest moon, Titan. Huygens is the first to provide us with a look at a world approximating primordial Earth. As Contributing Editor John Shibley explains in "Cassini's 4-year odyssey" (page 8), mission scientists have made other remarkable finds.

One planetary system stands out from the others in that it has not yet been visited — distant Pluto. But a NASA mission set for launch in early 2006 will explore Pluto and its moon Charon, an odd system that consists of two objects from the icy Kuiper Belt. Christened New Horizons, the mission will provide an up-close look at Pluto and its moon in July 2015. In "First mission to the last planet" (page 36), S. Alan Stern, New Horizons' principal investigator, tells the compelling story behind the mission and what scientists hope to learn.

Explore the Universe 2006 also goes beyond the solar system, bringing you the story of astronomers' attempts to classify galaxies. The process started in earnest in the 1920s, when Edwin Hubble devised his "tuning fork" classification system. Caltech astronomer Christopher Conselice shows us how far the process has come, and how science can be a difficult and incremental process, in "An embarrassment of galaxies" (page 28).

Happy stargazing!

Yours truly,

Dave Eicher
Editor

Explore the UNIVERSE®

12th EDITION – 2006

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Cassini's 4-year ODY

Saturn's beauty is more than ring deep. /// BY JOHN SHIBLEY

NASA's current mission at Saturn would make an accountant proud of its bang for the buck, a fighter pilot thrilled with the number of "targets" it has hit, and a photographer ecstatic with its stunning images. NASA managed to pack four missions onto the Cassini spacecraft. One objective is to look at Saturn's small icy moons, the same type we see scattered throughout the outer solar system. Then there's the exploration of the enigmatic moon Titan, with its thick atmosphere that harkens back to primordial Earth. The planet's complex, one-of-a-kind ring system receives nearly constant scrutiny from the spacecraft's battery of instruments. And finally, Saturn is studied as a prime specimen of a gas-giant planet, the kind astronomers are discovering with increasing frequency around other stars.

Since the bus-size spacecraft arrived at Saturn June 30, 2004, it has filled in some of the gaps in our knowledge of the saturnian system. But there's plenty more to be learned before Cassini's primary mission wraps up in 2008.

SATURN APPEARS IN ALL ITS GLORY in this composite made from 28 separate pointings of Cassini's camera, each taken through four different filters. NASA/JPL/SSI

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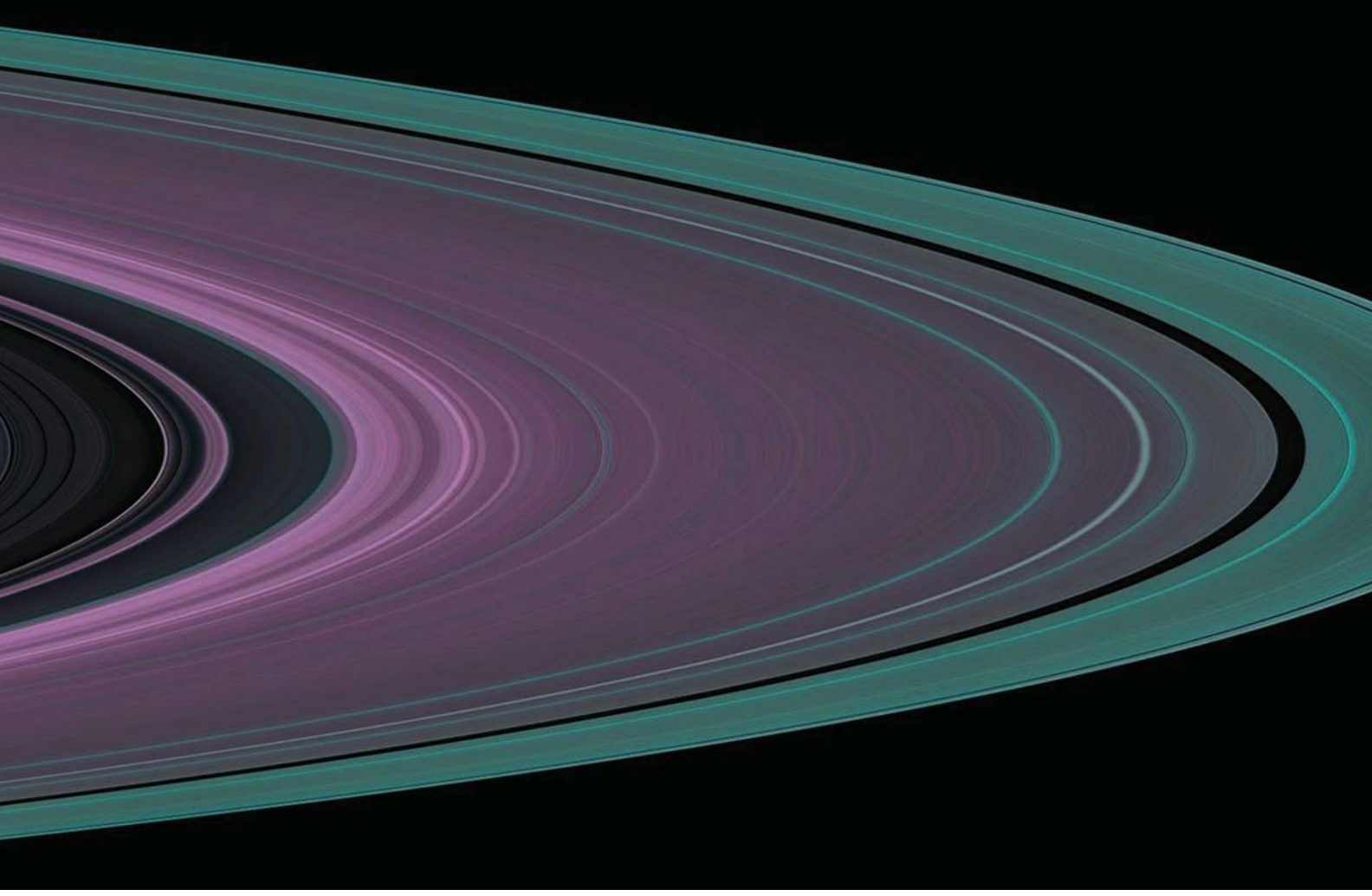


RING PARTICLES COLLIDE and fragment in the outer part of Saturn's A ring. Cassini beamed radio signals through the ring to Earth for scientists to create this profile. Green indicates regions where particles have been ground to less than 2 inches across, while purple regions contain bigger particles. NASA/JPL

Incredible Titan tour

The Titan portion of the Cassini mission is as exciting as winning the lottery for planetary scientists. Titan, larger than Mercury, is the second-largest moon in the solar system. But even more important, it is the only solar system moon with a dense atmosphere.

The European Space Agency's Huygens probe, which Cassini launched toward Titan in December 2004, made a quick entry and landing January 14, 2005. Huygens revealed a frigid world with channels cut by methane rain and dry (or damp) plains where the liquid runoff pools.

Huygens' single surface photo reveals a hazy vista with rocks of water ice stretching to the horizon. Titan's thick atmosphere — 1.5 times the surface pressure at sea level on Earth — belies an alien cryogenic ambience of –291° Fahrenheit (–180° Celsius).

Always a big fan of the space program, contributing editor **John Shibley** eagerly awaits each new image beamed back by Cassini.

What generates Titan's atmosphere is anyone's guess. Gravity alone can't hold the largely nitrogen atmosphere (with a few percent methane) in place. In fact, it is Titan's feeble gravity — just ⅐ as strong as Earth's — that allows the upper atmosphere to balloon out to 790 miles (1,270 kilometers), compared with Earth's 60-mile (100 km) threshold to space. Titan's ocean of gas should have leeched into space millions, if not billions, of years ago.

So what replenishes the atmosphere? Recent Cassini flybys show tantalizing hints of exceptional atmospheric roiling near the moon's south pole. This may point to an active cryovolcano — one at frigid temperatures that uses water, possibly mixed with liquid ammonia or methane, instead of the molten lava seen on Earth.

Scientists announced in June the first solid evidence for a Titan ice volcano. Infrared images taken during an early Cassini flyby show a circular feature about 19 miles (30 km) across that has a dark central feature resembling a volcano's caldera. The scientists think icy plumes brought material to the surface, creating the dome-like feature and releasing methane into Titan's atmosphere.

What could make Titan active? When planetary scientists encounter active moons, they first consider tidal heating. At Jupiter, the Galileo spacecraft found a hyperactive Io and probable oceans of liquid water inside Europa and Ganymede. All three are kept molten by tidal flexing between the planet and the other massive moons. But Saturn is much smaller than Jupiter, and when it comes to oversize saturnian moons, Titan is it. Tidal heating may supply some of Titan's internal heat, but it likely can't account for it all.

Perhaps we are witnessing the lingering effects from a geologically recent large impact. Cassini radar images in February revealed a large impact basin, and surely others await discovery.

Radar is probably Cassini's strongest tool for giving a rough idea of Titan's large-scale geology. The spacecraft's radar experiment can operate in three modes.

As a radiometer, it picks up heat emanating from Titan's surface. From this, investigators can discriminate water ice from frozen ammonia.

The radar dish also serves as an altimeter, teasing out surface elevations to an accuracy between 300 and 500 feet (90 and 150 meters). This resolution may be good enough to pick up on tidal flexing as Titan orbits Saturn, if any exists. Flexing may hint at a subsurface ocean of water or ammonia under several miles of ice.

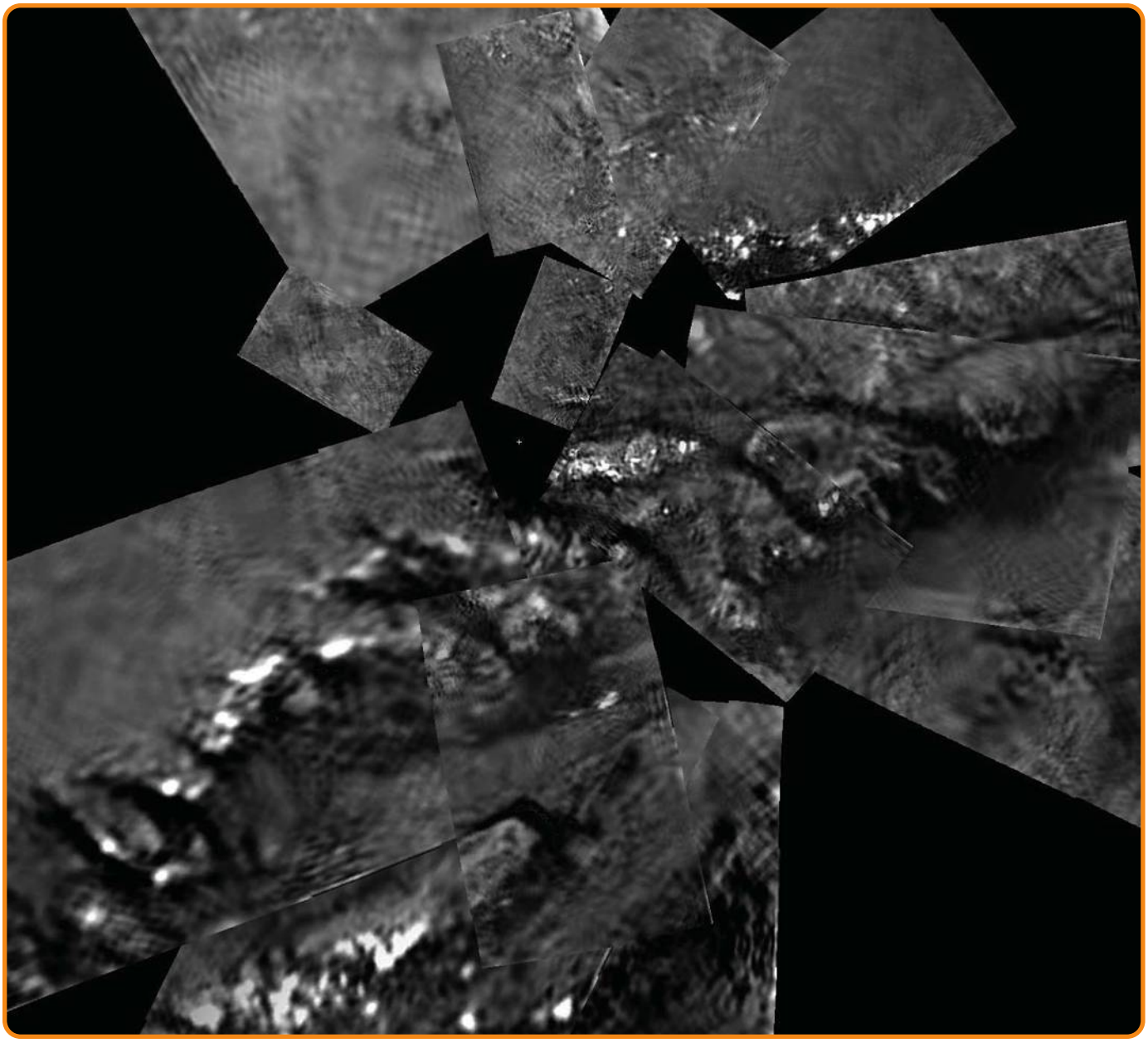
Finally, Cassini's radar can operate in imaging mode. The spacecraft beams radio pulses at Titan's surface and then records the signals that bounce back. The data allow scientists to construct quality surface images through the haze-choked atmosphere. In the early 1990s, the Magellan spacecraft used this same radar sleight of hand to pierce Venus' clouds.

Cassini's radar images reveal features as small as 1,150 feet (350m) across at closest approach. With this technique, each favorable flyby promises to capture about 1 percent of Titan's surface. By 2008, almost 35 percent of Titan's landscape will have been mapped in this way.

If Titan is still molten on the inside, or has a subterranean ocean, Cassini's onboard magnetometer should reveal a magnetic field. We likely will know the answer by the end of 2005, thanks to more favorable encounter geometry.

Subsequent close encounters also will let Cassini's instruments sample gases in Titan's tenuous upper atmosphere. This will provide clues as to what continues to create them.

Mission planners accrue experience and expertise with each flyby, and with more than 40 encounters scheduled through 2008, this adds up to a lot of knowledge. Planetary scientists will learn about Titan's gravitational and atmospheric variables. Trajectory engineers can



HUYGENS RETURNED THIS MOSIAC as it descended by parachute to Titan's surface January 14, 2005. The image shows the landing site from a height of 2,625 feet and covers an area approximately 4,265 feet across. Light areas likely are ridges, while the darker areas appear to be channels created by methane rain. ESA/NASA/JPL/UNIVERSITY OF ARIZONA

LANDSLIDES ALONG THE RIM of Phoebe's fresh craters reveal white water ice through a thin veneer of darker, older ices that has been weathered by eons of solar radiation. NASA/JPL/SSI

THE PURE WHITE RAMPARTS of the crater named Jason are ice cliffs 12 miles high. The faces were probably created when impacts elsewhere on Phoebe jostled massive landslides along the crater's walls. NASA/JPL/SSI

push the envelope, so Cassini itself essentially becomes an atmospheric probe.

Encounters with Enceladus

Titan's atmosphere has long screamed out for study. But what of the more subtle air discovered recently around Saturn's moon Enceladus?

Despite being small enough to fit inside Arizona's borders, Enceladus has the hallmarks of a geologically active moon. In places, its face has been resurfaced completely during the past 5 million to 200 million years.

The blazing white surface reflects nearly all of the sunlight hitting it. Also, Saturn's E ring reaches its highest density in the same region as Enceladus' orbital distance from Saturn.

During a March 9, 2005, flyby at an altitude of just 310 miles (500 km), Cassini's magnetometer picked up distortions in Saturn's ambient magnetic field that wraps around Enceladus. This nailed down the signature of an atmosphere. Telltale oscillations in the magnetic field even betrayed the presence of water vapor.

But the tenuous atmosphere's source awaits discovery. Additional close flybys in July 2005 and March 2008, along with the results from months of studying close-up photos of the moon's landforms, may reveal active geysers.

If this turns out to be the case, Enceladus will join only one other icy moon in the solar system, Neptune's Triton, with known active geysers. The Voyager 2 spacecraft found Triton's gushers during a 1989 encounter, 8 years after that well-traveled spacecraft flew within 55,000 miles (90,000 km) of Enceladus for a close look.

But what heats an otherwise dormant Enceladus? Some scientists believe it's tidal tugging between Saturn and a larger moon, Dione, which orbits Saturn once in the time it takes Enceladus to orbit twice. All of Saturn's moons appear to have significant proportions of surface ammonia ice, which has a far lower melting point (–108° F, or –78° C) than frozen water. Somehow, either through tidal flexing or impacts, Saturn's moons are prone to meltdowns.

HUYGENS' SINGLE surface photo reveals a hazy vista with rocks of water ice stretching to the horizon.

First-class ring world

Enceladus' subtle contribution to Saturn's E ring underscores just how hard it is to draw a line between where studies of Saturn's satellites end and its rings begin. Saturn has many more than 47 known moons. It's home to a cast of billions.

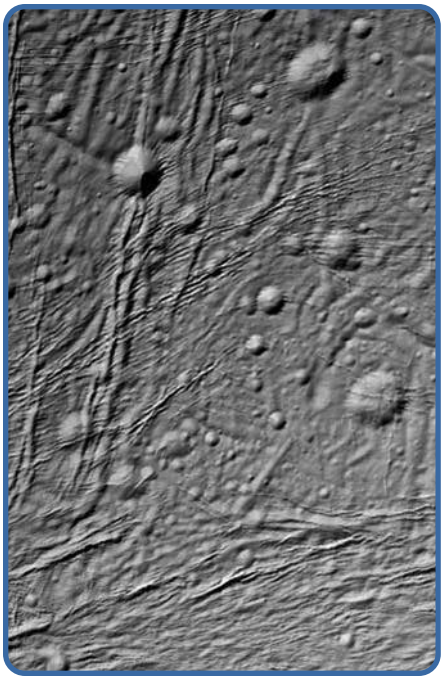
Welcome to Saturn's glorious rings.

It's here that rock and ice particles — ranging in size from tiny grains to the bulk of a house — trace out their own orbits around Saturn. The rings could be an aborted moon, the remains of one or more shattered moons, or stuff swept up from eons of incoming meteoroids and comets. They undoubtedly contain material sloughed off, or belched from, other saturnian moons.

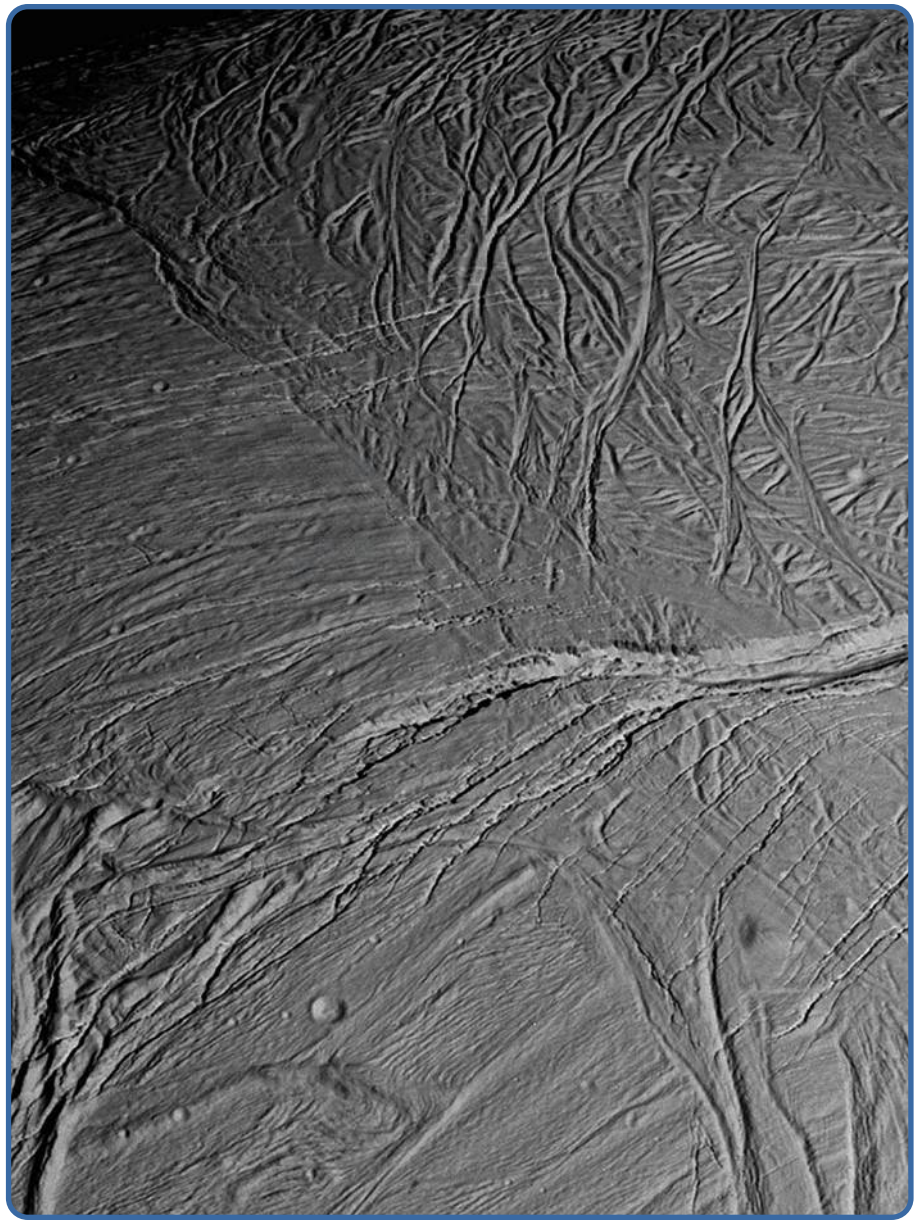
Although the main rings span 175,000 miles (280,000 km), astonishingly, they measure less than 1 mile thick.

Early in Cassini's sojourn, onboard spectrometers sniffed out molecular oxygen above the ring plane. The data suggest high-energy particles trapped in Saturn's magnetic field chip atoms off of the water ice that makes up the bulk of the rings.

Saturn's myriad moons create many of the major features seen in the rings. Resonances — in which the orbital periods of a moon and a ring particle differ by a simple fraction — produce gaps and sharp edges in the rings.



FRACTURES SCORE much of Enceladus. They cut across impact craters, indicating the rifts formed later in the moon's history. NASA/JPL/SSI



A BROAD RIFT about 3 miles wide dominates this area of Enceladus, scarred with many interweaving fractures. These tectonic features imply this moon still may be geologically active. NASA/JPL/SSI

For example, the sharp outer edge of Saturn's A ring results from a 7:6 resonance with the moons Janus and Epimetheus. Two moons that orbit slightly offset from each other can confine ring particles lying between the moons in a phenomenon called "shepherding."

The thin, twisted F ring is shepherded by Pandora and Prometheus. All these moons are tiny, less than 125 miles (200 km) in diameter.

Cassini drew closest to the rings when it entered Saturn orbit in late June 2004. Spectacular pictures captured intriguing density waves in Saturn's A ring, which is molded and continually shaped by two other small moons: Pan and Atlas.

The waves represent these moons' gravitational palm prints. Syncopated passes by Pan and Atlas sift ring material by its density. By studying how these waves form in the A ring, planetary scientists deduced that the two moons are likely rubble piles held together loosely by gravity. Still finer braids and ripples throughout the rings suggest the presence of embedded moons yet to be discovered.

Pan's orbital dynamics in the rings' dusty environment also may show how planets wander through dusty protoplanetary disks around other stars. Many extrasolar planets have been found with surprisingly eccentric orbits. As if to echo this theme and variation, tiny Pan's interaction with Saturn's ring material gave the moon an inclined and eccentric orbit.

We will enjoy ringside seats to Pan and company's activities when Cassini settles into a spectacular, high-inclination orbit between July 22, 2006, and June 30, 2007.

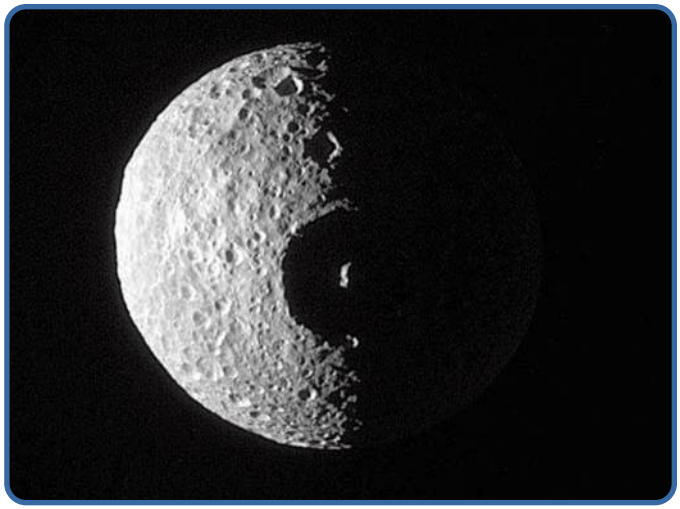
A giant's family

A series of Titan flybys from September 7, 2005, through July 22, 2006, will modify Cassini's orbit so the spacecraft's farthest point from Saturn stands directly above the planet's night side, deliberately downstream from the Sun.

This zone, called the magnetotail, is where the solar wind blows Saturn's magnetic field into a tail that traps charged particles from the Sun. Planetary scientists are eager to learn more about Saturn's magnetic wake. During this phase of the mission, Cassini's magnetospheric, atmospheric, and plasma science instruments will come into their element.

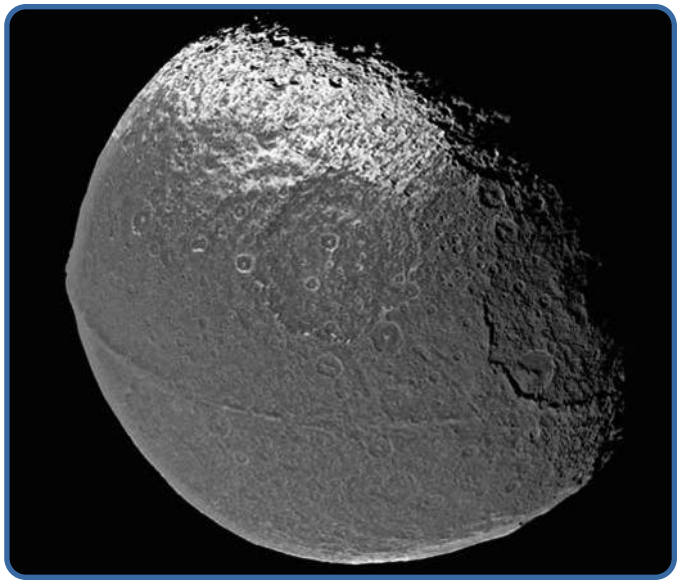
The magnetotail almost crackles with charged particles that flow away from Saturn. In some places, streams double back to the planet, where they create spectacular aurorae. Expect Cassini to send back striking images of Saturn's northern and southern lights during this period. Earth's aurorae pale in comparison — the Hubble Space Telescope has picked up Saturn's ghostly glows.

CRATERS HEAPED ON CRATERS on 600-mile-wide Tethys underscore an ancient surface. The troughs are fault lines where the icy crust shifted during reheating, perhaps after a large impact elsewhere on the moon. NASA/JPL/SSI



THE CRATER HERSCHEL dwarfs all others on Mimas. The formation of this 80-mile-wide impact basin almost blew apart the moon, which is only 247 miles across. NASA/JPL/SSI

BRIGHT, WISPY TERRAIN on Rhea's trailing hemisphere looks like a thin coating painted on the moon's surface. Future flybys could resolve them into long, narrow, and braided fractures. NASA/JPL/SSI



QUIRKY IAPETUS has one face as white as freshly fallen snow while the other is as dark as asphalt. An 8-mile-high ridge stretching 800 miles runs along the moon's equator. NASA/JPL/SSI

During this phase of the mission, the spacecraft's orbit also lies in the plane of Saturn's rings and most of its icy satellites. This offers up the mission's best encounters with the intermediate-size moons Hyperion (September 25, 2005), Dione (October 11), and Rhea (November 26).

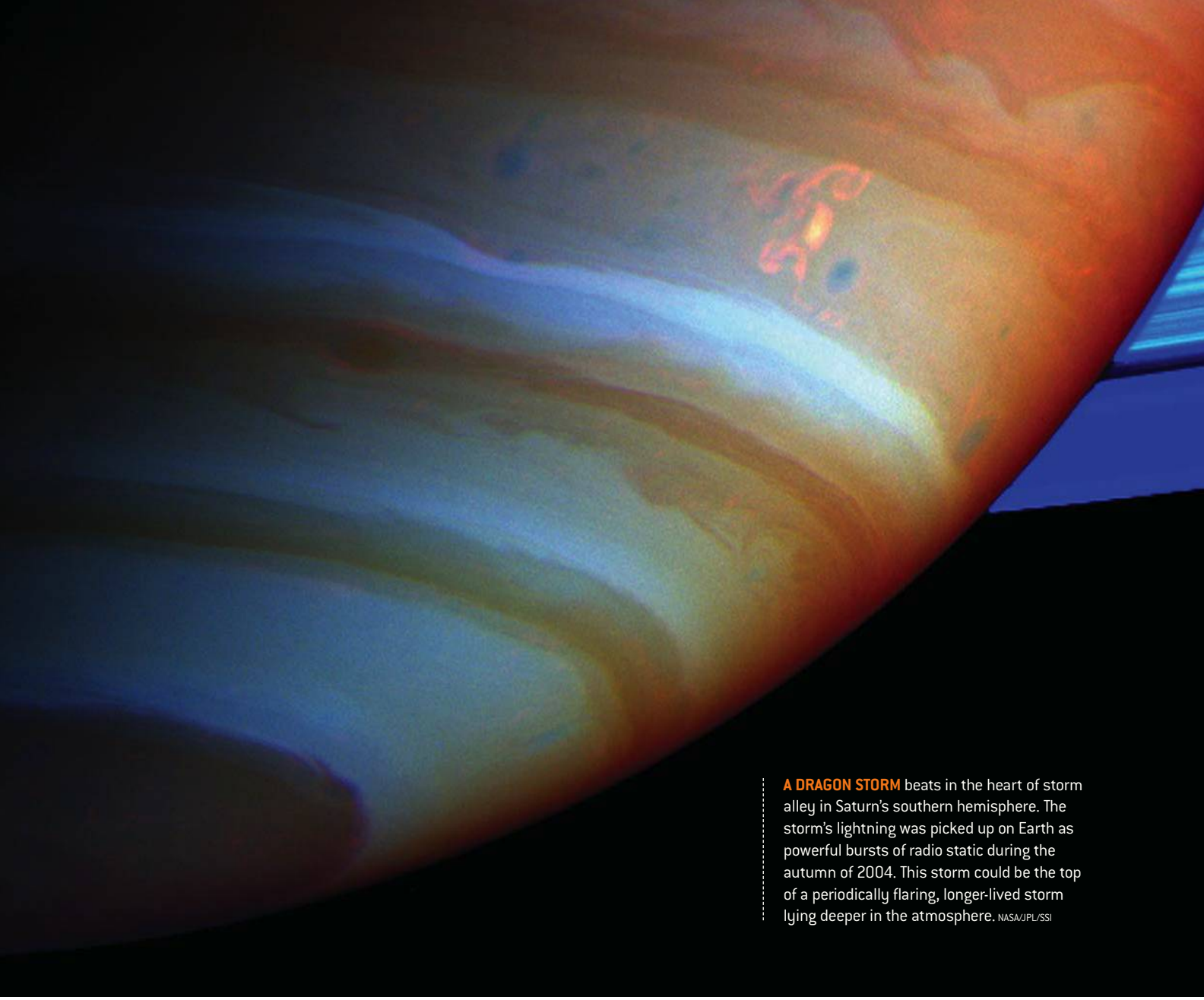
A pass 630 miles (1,010 km) above Hyperion September 25 gives us a good look at a truly queer saturnian ice moon. Shaped like a hamburger patty, Hyperion has a long dimension of 230 miles (370 km). It orbits beyond Titan with a period slightly longer than Titan's. Hyperion's strange shape, coupled with Titan's tugging, makes the smaller moon tumble chaotically. Sometimes Hyperion changes spin and rotates backward.

Hyperion's irregular shape speaks of a whacked and shattered pedigree. Models suggest some of Hyperion's material ended up on Titan, providing a possible smoking gun for what makes Titan tick so loudly today. Lingering heat from a cosmically recent impact could account for Titan's current geologic activity. And debris from Hyperion could partially explain why one of Iapetus' hemispheres is so dark.

Planetary scientists eagerly await the November 26, 2005, encounter with Rhea, Saturn's second largest moon with a diameter of 950 miles (1,530 km). Rhea has bright, wispy streaks that might be caused by cryovolcanism. It's also pocked with many small, and perhaps reasonably fresh, craters that could point to a long-ago bashing by rocky debris from Hyperion.

The end, or a new beginning?

Saturn's massive atmosphere comes under scrutiny during the next chapter in Cassini's tour, which runs between July 22, 2006, and June 30, 2007. Several Titan flybys will lift the craft's orbit so it inclines steeply to the planet's equator and Cassini's farthest point from Saturn lies above the daylight hemisphere. This affords not only a sweeping vista of the rings, but also



A DRAGON STORM beats in the heart of storm alley in Saturn's southern hemisphere. The storm's lightning was picked up on Earth as powerful bursts of radio static during the autumn of 2004. This storm could be the top of a periodically flaring, longer-lived storm lying deeper in the atmosphere. NASA/JPL/SSI

stunning and continuous views of Saturn's atmosphere practically from pole to pole.

Thanks to orbital pumping from two Titan flybys July 18 and August 31, 2007, Cassini will line up for its first and only close approach to Iapetus. On September 10, the spacecraft flies 765 miles (1,230 km) above the boundary between that moon's snow-white and coal-black hemispheres. Science-fiction aficionados will recall Iapetus as the place where aliens placed a star gate in Arthur C. Clarke's original version of *2001: A Space Odyssey*.

For the end run of Cassini's prime mission, Titan encounters draw the spacecraft in for closer views of the ring system. Each Titan flyby tightens the orbit for what should be the spacecraft's most spectacular ring imaging.

By then, the ring spokes made famous by the twin Voyager probes in the early 1980s could become visible. They've been conspicuous in their absence during the early stages of Cassini's tour.

The spokes are electrostatically charged particles suspended in silhouette above Saturn's main rings. Scientists think their appearance could vary with the 11-year cycle of solar activity, or depend on where Saturn lies in its 29.5-year orbit around the Sun.

One of Cassini's closest passes of Enceladus comes March 12, 2008, near the conclusion of the prime mission. The spacecraft's high-inclination orbit will provide detailed views of previously unseen terrain on the active moon.

What tasks may await Cassini after the prime mission wraps up July 1, 2008, depends largely on how much of the craft's maneuvering gas remains. It should have enough fuel and power for an extended mission. The plutonium that generates Cassini's heat and electricity will last well beyond the primary mission.

Scientists hope NASA approves an extended mission that will take in better and riskier views of the rings. Or maybe the risk factor gets cashed in for more ambitious Titan encounters.

One thing's for certain: Cassini will wind up the same way Galileo did at Jupiter. Rather than run the risk of contaminating a moon by crashing into it, Cassini will burn up as it augers into the planet's upper atmosphere. Thankfully, it will be at least a decade before Cassini goes down in its own blaze of glory. A

The Red Planet: Seeking far horizons

You'd think it's a whole new world out there, as two rovers and three orbiters rewrite the book on Mars.

/// BY ROBERT BURNHAM

TODAY, FIVE SPACECRAFT — more than ever before — are studying the Red Planet. Two rovers on the ground and three in martian orbit are firing Mars data back to Earth — and a sixth stands poised on the launch pad.

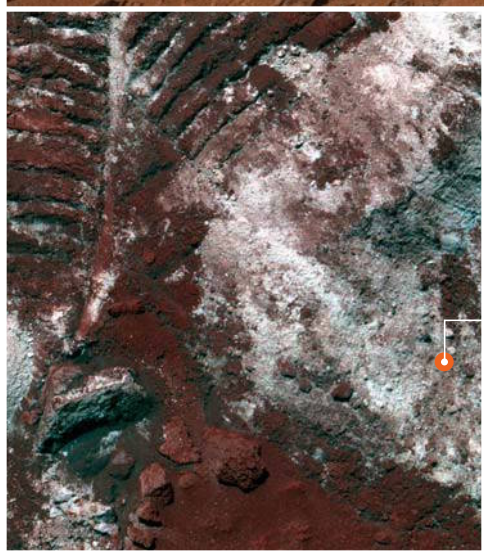
This fleet is carrying out a goal that NASA describes as "following the water," a strategy scientists designed to find out if Mars has a biosphere now — or ever had one in the past.

While no one knows exactly how life began on Earth, liquid water appears to have been an essential ingredient. Water, then, is the key to life as we know it, and if Mars ever had life, the first place to look for its traces is wherever water has seeped, trickled, or flowed.

Terrestrial armada

Orbiting Mars are Mars Global Surveyor (which arrived in 1997), Mars Odyssey (2001), and Mars Express (2003). Ready for launch August 10 is the Mars Reconnaissance Orbiter, slated to arrive in March 2006.

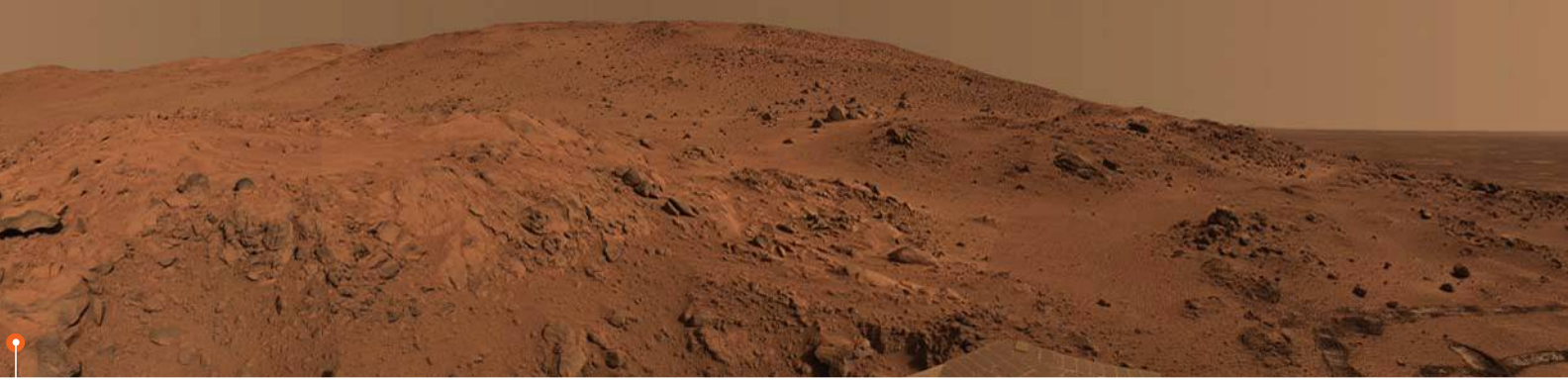
Rolling on the martian surface are two Mars Exploration Rovers, which landed in January 2004 on opposite sides of the planet. Designed to last just 90 sols (90 martian days), or about 3 Earth months, they have been operating for more than 500 sols, or nearly 18 Earth months. (One sol lasts 24 hours and 39 minutes.) The rovers have driven about 5 miles each, making the first geological field trips across the Red Planet.



Rocks on a martian hillside: NASA's rover Spirit in Gusev Crater

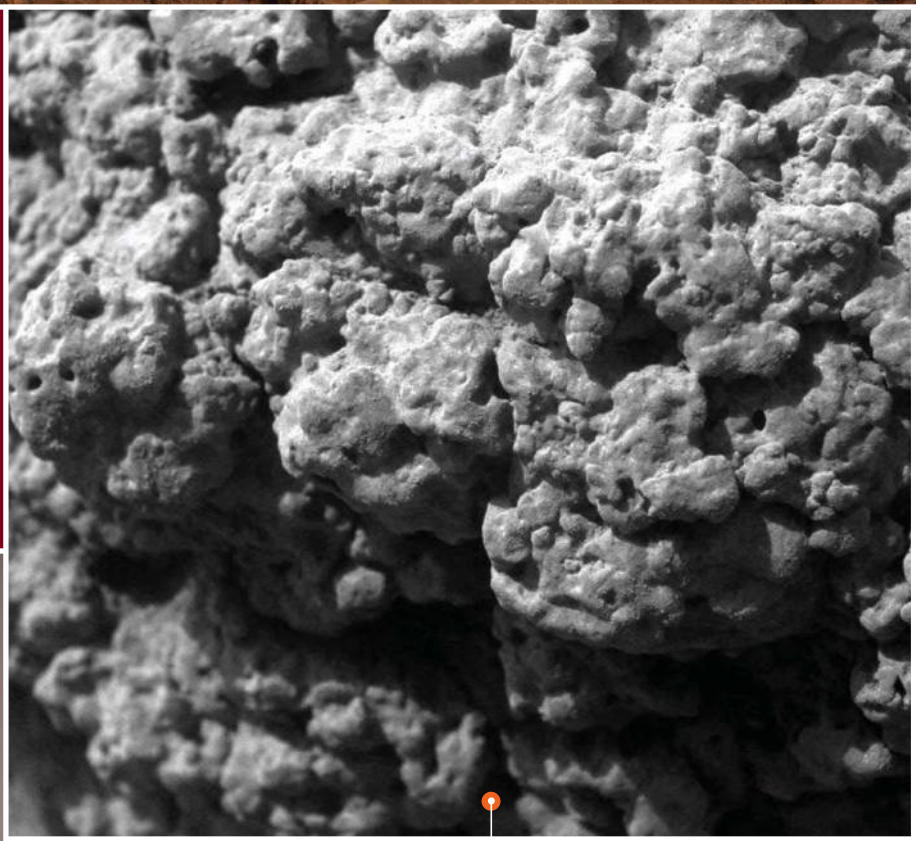
RIGHT THE SETTING SUN DIPS below the rim of Gusev, 50 miles away. Such images, besides being simply beautiful, tell about clouds and dust in the atmosphere. NASA/JPL/TEXAS A&M/CORNELL

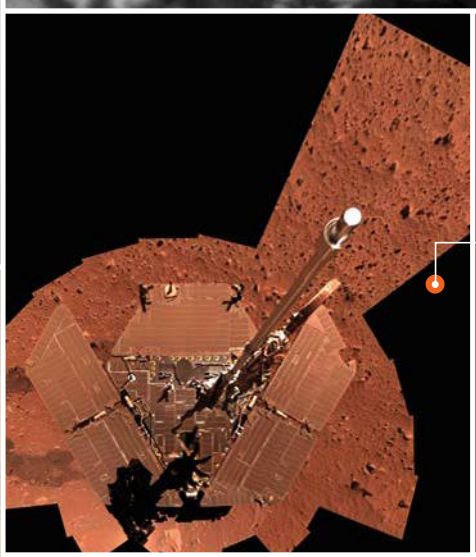
LEFT WHEN SPIRIT TURNED BACK from climbing Husband Hill, scientists saw this vista. At left is Clark Hill, while in the far distance at right is the rim of Thira Crater. The long, crumbling outcrop in the foreground is Larry's Lookout, with an area named Methuselah on the left end and Jibsheet on the right. NASA/JPL/CORNELL



ABOVE AT A SITE NAMED LARRY'S LOOKOUT, Spirit took a wide-angle view in natural color that encompasses the Columbia Hills and the Gusev plain, at right. When Spirit attempted to drive straight up Husband Hill, in the center, its wheels started slipping, and scientists turned it back to explore this area in more detail. NASA/JPL/CORNELL

LEFT HIGH IN THE HILLS, Spirit ran across sulfate-laden ground at a site dubbed Paso Robles. Redder soil in this false-color view is richer in iron, while white and bluish-white areas contain lots of sulfur. The disturbed patch is about 16 inches (40cm) across. NASA/JPL/CORNELL





ABOVE IN SPIRIT'S MICRO-IMAGER, Methuselah's texture tells scientists of its volcanic pedigree — deposited as ash or a hot flow of debris, and subsequently altered by water. NASA/JPL/CORNELL

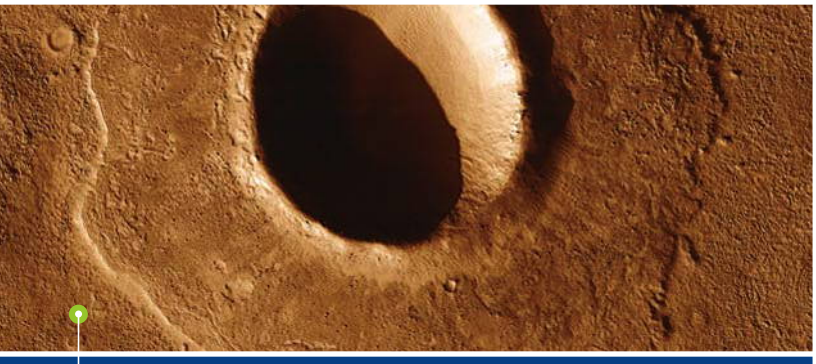
LEFT SPIRIT'S SELF-PORTRAIT shows solar panels coated with dust, which reduces their efficiency. In March 2005 (after this image was made), a dust devil blew across the rover, cleaning the panels and restoring most of Spirit's solar power. Compare the color of the Gusev soil with that on Meridiani Planum (page 26). NASA/JPL/CORNELL

LEFT AS SPIRIT PREPARES TO STUDY part of Methuselah, a dust devil whirls in the background of this image taken with the rover's hazard-avoidance camera. NASA/JPL/CORNELL

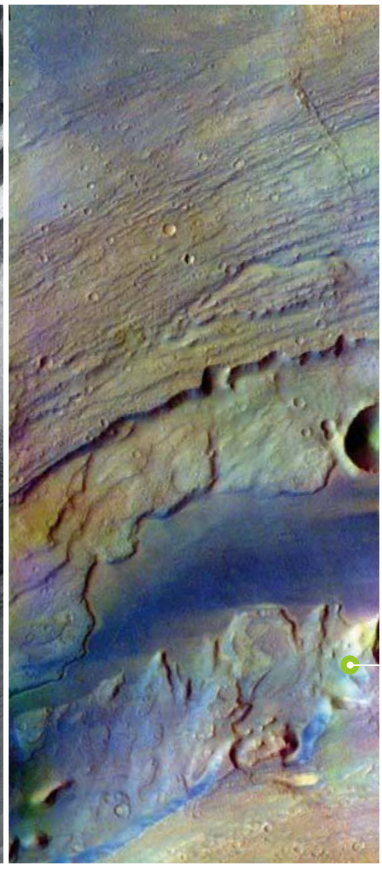
Probing the surface: NASA's Mars Global Surveyor and Mars Odyssey

ABOVE GULLIES AND APRONS OF DEBRIS on crater walls and hillsides point to erosion by flowing water in the geologically recent past. The water could come from buried aquifers and be released by solar heating. The image spans about 1 mile, top to bottom. NASA/JPL/MSSS

RIGHT Dark dunes crawl across the floor of Chasma Boreale, a large valley cutting into the north polar cap, seen at bottom in this MOC image, 1.9 miles wide. The sand making up the dunes may be volcanic ash that weathered out of the ice cap. NASA/JPL/MSSS



ABOVE A blanket of ejected debris around this crater in Noachis Terra protected the underlying surface from erosion. This gave the crater an elevated look. This MOC image spans 1.9 miles, top to bottom. NASA/JPL/MSSS



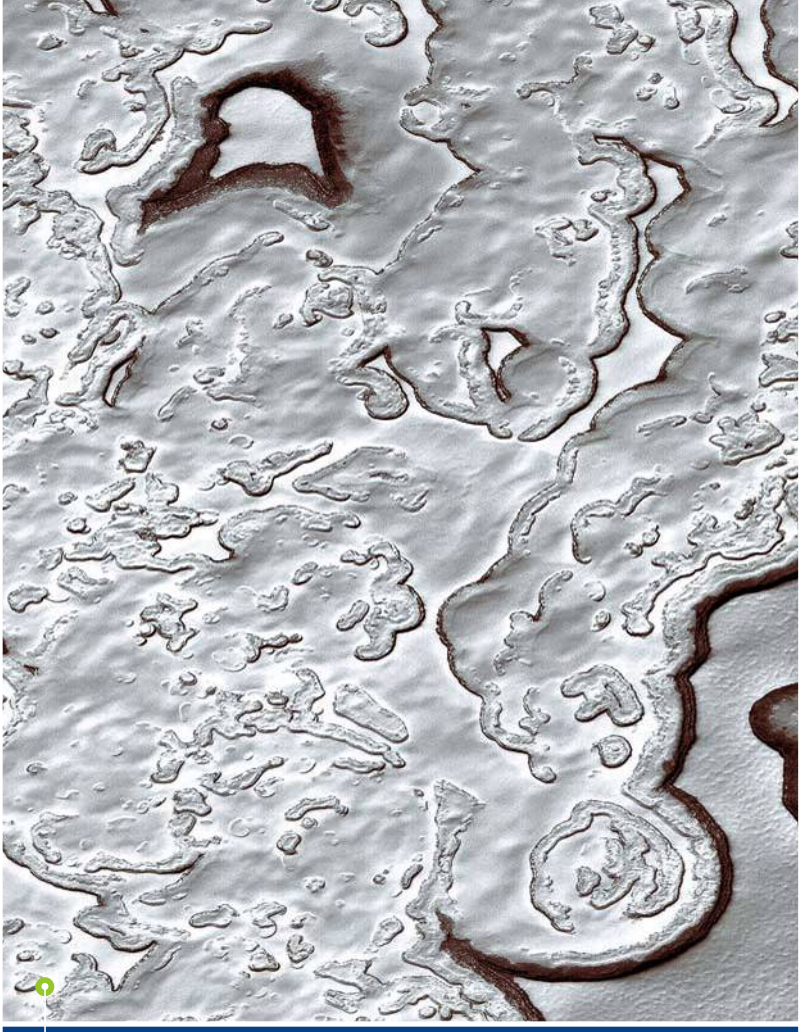
Both rovers have already achieved their intended mission goal: to find direct evidence of wet environments in the martian past. Whether these environments actually contained life remains unknown, but according to scientists, some terrestrial organisms could have survived in them.

While the rovers probe rock outcrops on the surface, the orbiters overhead are drawing a portrait of the planet in broader strokes, letting geologists assemble a detailed picture of the planet's past. The story these five spacecraft have to tell is of a cold, hostile desert world — yet as the rover images show, it's also starkly beautiful. But was it once home to life? Stay tuned.

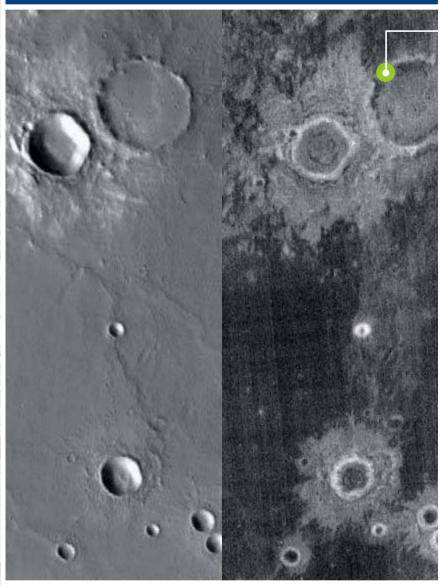
Eyes in the martian sky

The current exploration wave began with the arrivals of Mars Pathfinder (July 1997) and Mars Global Surveyor (September 1997), both sent by NASA. Pathfinder was a stationary lander that carried a small, solar-powered rover named Sojourner, about the size of a microwave oven.

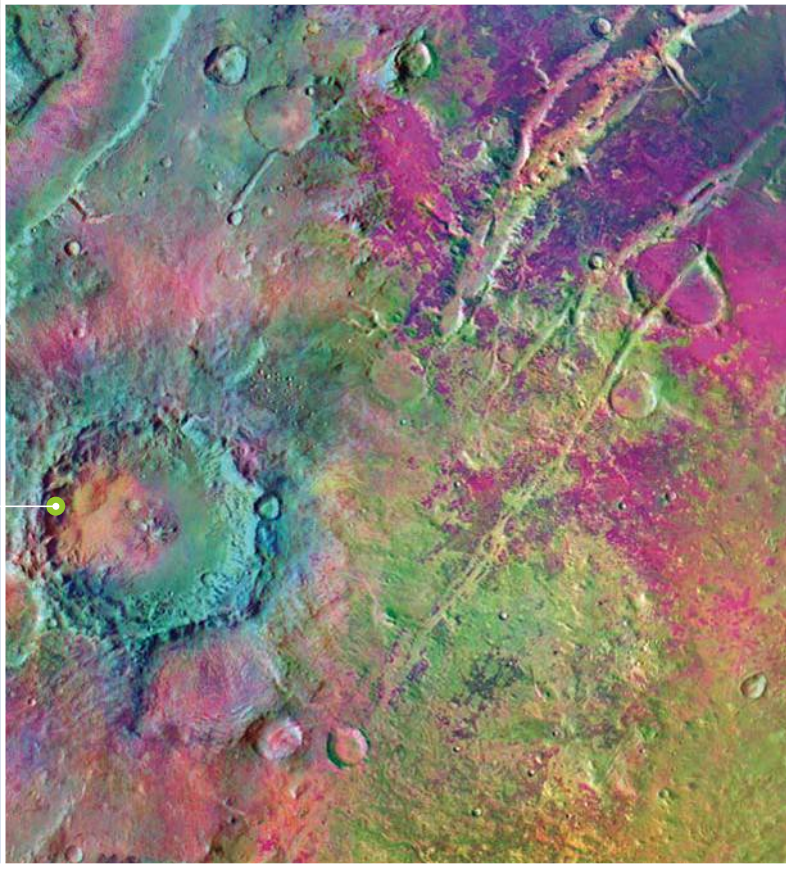
Pathfinder landed in Ares Vallis, a region scientists believe is an ancient channel for catastrophic floods. Surface views show a tangled wilderness of rocks, sand, and dust, with a double hill, which scientists dubbed Twin Peaks, standing about half a mile (1 kilometer) to the southwest.



ABOVE CURLIQUE MESAS AND PITS form in the south polar cap, as frozen carbon-dioxide ice evaporates. In its wake, it leaves behind dark, dust-rich slopes, seen in this natural-color view from the MOC imager on Mars Global Surveyor. The area shown is about 1.8 miles wide. NASA/JPL/MSSS



LEFT WHERE THE ROCKS ARE is as clear as night in these two THEMIS images of the same area. At far left is the daytime view. At near left is the same scene at night, with rock-strewn areas glowing as they give up heat absorbed during daytime. Note how aprons of warm rocks surround craters. Each view is 20 miles wide. NASA/JPL/ASU



LEFT KASEI VALLIS WAS CARVED by a catastrophic flow of water, probably released when ice in the ground melted as volcanic activity erupted. Dust (shown in cool tints) has collected on the channel floor; the water flowed from left to right. This THEMIS image is 16 miles across. NASA/JPL/ASU

RIGHT OLIVINE DECOMPOSES quickly when wet. This THEMIS image of the Nili Fossae region shows where olivine lies at the surface (magenta to bluish-purple colors). Olivine's widespread appearance in an old landscape suggests that Mars has been cold and dry for much of its history. NASA/JPL/ASU

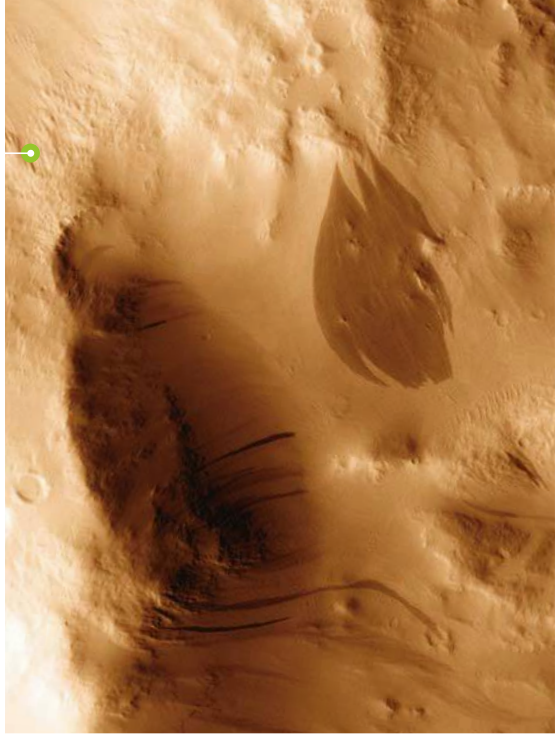
The scenery was striking, but the star of the show was Sojourner, especially for the public, who avidly followed mission events on the Internet. The six-wheel rover trundled down off the lander and drove to dozens of nearby rocks, finding some resembling parts of Earth's continental crust in composition.

Pathfinder's mission lasted about 3 months. Its instruments pointed to an ancient Mars a lot warmer and wetter than today. But the findings also suggested that present martian conditions — cold and dry — have prevailed for 2 to 3 billion years.

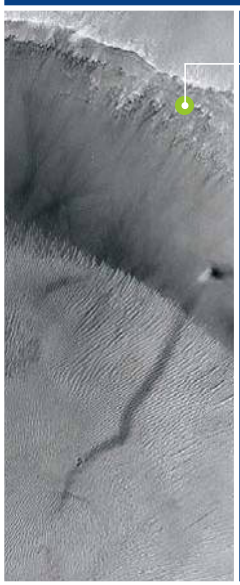
Arriving a few months after Pathfinder was the Mars Global Surveyor (MGS) orbiter, still in operation. It carries several instruments that duplicate ones lost when the earlier Mars Observer probe failed in 1993. Three MGS instruments have revolutionized scientists' picture of Mars.

The Mars Observer Camera (MOC) photographs the surface, spotting details only 5 feet (1.5 meters) across. MOC images show gullies on the walls of craters and mesas that suggest present-day sources of liquid water (like aquifers) lie at or close to the surface. The images have also caught dust devils in mid-whirl and cataloged seasonal changes in the polar ice caps.

The Mars Observer Laser Altimeter (MOLA) made about 640 million surface elevation measurements before a key part of the

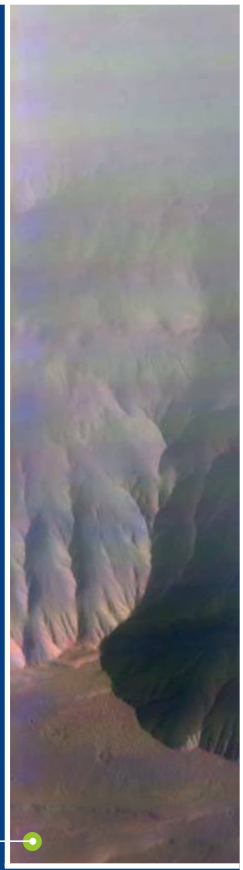


RIGHT STREAKS ON SLOPES are common in images of hills, mesas, and craters. Images taken only a few months apart sometimes show new streaks. Scientists think the streaks are tracks of dust avalanches that leave bare rock behind. But some streaks may be brine seeps. NASA/JPL/MSSS

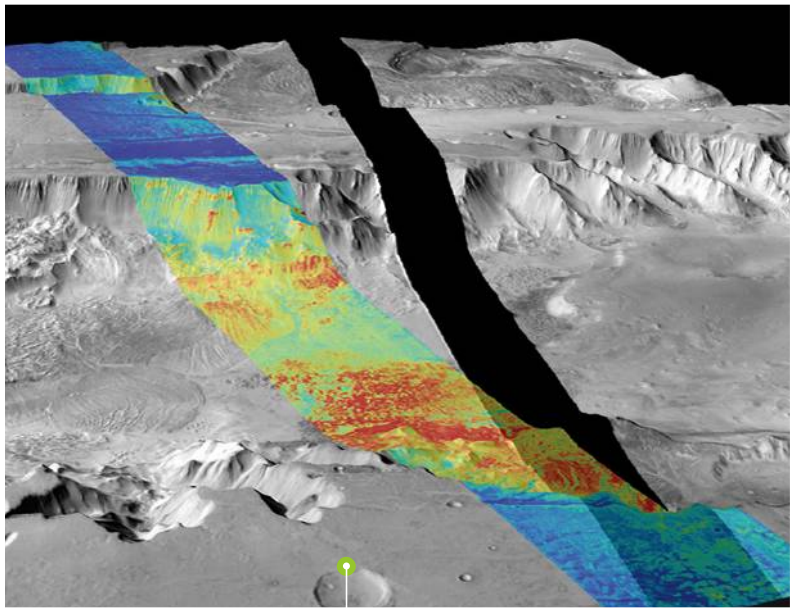


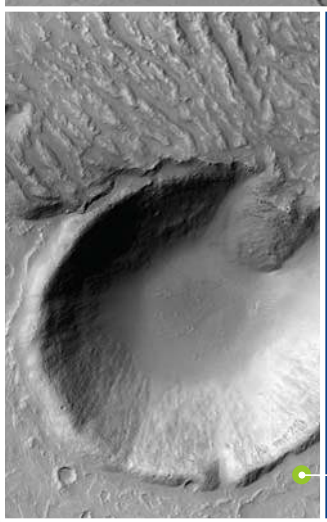
LEFT SCRIBING A TRAIL, a dust devil climbs a crater wall in this MOC image. Such whirlwinds behave much like terrestrial ones and leave a dark track because they blow light-colored dust off the surface. The view spans about 1.9 miles. NASA/JPL/MSSS

BELOW BARBED WIRE? This fault cuts across a crater's smooth floor, with a few side-channels indicating lateral collapse and erosion. The THEMIS image is about 16 miles wide. NASA/JPL/ASU



ABOVE WINTER HAZE FILLS Coprates Chasma, part of the vast Valles Marineris feature, in this false-color THEMIS image. The local time was about 5 P.M. The image spans 16 miles. NASA/JPL/ASU





ABOVE COMBINED DAY AND NIGHT VIEWS by THEMIS of Melas Chasma in Valles Marineris use false color to separate rocky areas from those that are sandy and dusty. Red is warmer, which indicates a higher proportion of rock at the surface; conversely, blue is cooler and dustier. NASA/JPL/ASU

LEFT A LARGE LAVA FLOW in Tharsis almost engulfed this impact crater, spotted by the MOC imager. The scene spans 1.9 miles. NASA/JPL/MSSS

instrument failed in 2001. MOLA elevations gave scientists their first accurate map of martian topography, revealing subtle slopes, watershed basins, possible ancient beach lines, and almost eradicated "ghost" craters in the northern lowlands.

Also aboard MGS is a Thermal Emission Spectrometer (TES). It identified a Connecticut-size region near the equator with a lot of hematite, a water-associated mineral, on the surface. This became a prime target when NASA was picking sites for the rovers, and one of them (Opportunity) landed there.

Following MGS were two NASA Mars spacecraft that crashed, both in 1999: Mars Climate Orbiter and Mars Polar Lander. Although the failures were big setbacks, scientists have recovered most of the lost missions' data by flying duplicate instruments on missions that are now in operation.

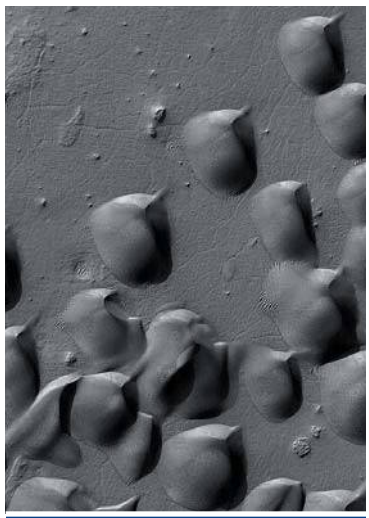
Arriving in October 2001 was NASA's Mars Odyssey. Its prime instruments are a Thermal Emission Mapping Spectrometer (THEMIS) and a Gamma-ray Spectrometer (GRS). The GRS found that outside of Mars' equatorial region, water (probably as ice) lies just below the surface in many places, often in quantities that suggest the ground is half ice by volume. THEMIS draws detailed maps of surface mineralogy and, passing over the nightside hemisphere, it uses heat emission from the ground to chart where the surface is rocky or dusty.

A recent THEMIS study found one flank of the volcano Syrtis Major contains a lot of the greenish volcanic mineral olivine, which weathers easily when water is present. With the region's lava flows dating to about 3 billion years ago, the new finding supports the idea that the martian climate has been dry and cold for most of the planet's history.

On Christmas Eve, 2003, Mars Express, launched by the European Space Agency (ESA), reached Mars and dropped off a lander, Beagle 2, before going into orbit. Unfortunately, Beagle 2 was never heard from again, and presumably crashed. Mars Express, however, has been a signal success.

The spacecraft's High Resolution Stereo Camera images the entire planet, seeing details as small as 30 feet (10m) wide overall, and as small as 7 feet (2m) in selected areas. Infrared, visible, and ultraviolet spectrometers examine the atmosphere's composition and map the surface's mineralogy. A ground-penetrating radar, MARSIS, has begun to look for water or ice, down to a depth of a mile or two (a few kilometers). It was fully deployed late — in June 2005 — because mission controllers were concerned its two 60-foot (20m) booms would whiplash the spacecraft as they unfolded.

Mars Express' most intriguing find is trace quantities of methane in the martian atmosphere. While on Earth biological sources produce methane as a waste product — think of cows — the gas can also arise from weathering of volcanic rocks, such as olivine. Scientists say that if Mars has lots of olivine buried in its crust, and if in places it has water to weather the mineral, then a biological methane source isn't necessary.



WINDS BLOW LEAF-SHAPE DUNES across the floor of Wirtz Crater. Their shape indicates the wind blows from the southwest (lower left) toward the northeast (upper right). This MOC image is 1.9 miles wide. NASA/JPL/MSSS

Hot wheels on dirt

NASA's twin Mars Exploration Rovers (MERs) arrived at Mars on the heels of Mars Express. At their landing sites, autumn was deepening toward winter. The two golf-cart-size rovers, Spirit and Opportunity, have spent almost an Earth year and a half on the ground, on opposite sides of Mars from each other.

In their journeys, the rovers have alternated the leading role in discovery. Opportunity struck paydirt initially, then got stuck in a sand dune before pushing on. Meanwhile, Spirit trudged through relatively unproductive terrain for 5 months until it, too, finally hit the jackpot.

First to land was Spirit, January 5, 2004, in Gusev Crater. The site was chosen because preflight reconnaissance suggested Gusev had once been home to a lake fed by floods of water that coursed through Ma'adim Vallis, a valley channel that enters the crater through its southern rim.

Spirit's identical twin, Opportunity, followed with a landing January 25, setting down on Meridiani Planum. This site was chosen because orbital surveys from MGS and Odyssey showed the ground has a high abundance of hematite, an iron-oxide mineral that typically forms in association with water.

View from Gusev

Seen from orbit, Gusev's flat floor, 95 miles (150 km) across, held out the promise of abundant lakebed deposits. But scientists operating Spirit after its landing found themselves looking glumly at one basaltic rock after another.

Basalt is the most common volcanic rock in the solar system, and its molten flows destroy any living organisms they touch. Even after close examination, including drilling, each of the rocks around the landing site showed only the slightest signs of alteration by water. The conclusion was inescapable: The sought-for lakebed materials were nowhere to be found where Spirit landed, at least on the surface.

Scientists then looked to the northeast, where a nearby crater, 700 feet (210m) across and dubbed Bonneville, exposed layers 30 feet (10m) below the floor of Gusev. It took Spirit more than 50 sols to work its way across the apron of rubble ejected in the crater's impact. On finally reaching Bonneville's rim, Spirit peered inside — and found only more basaltic dust, sand, gravel, and rock.

"The ejecta from Bonneville didn't get excavated from deep enough to go below the volcanic layer," says deputy principal investigator Ray Arvidson of Washington University.

Thwarted twice, mission scientists looked to the southeast. Forming the skyline there is a range of hills about 300 feet (90m) high. It was named the Columbia Hills shortly after Spirit landed to commemorate the astronauts who died in the crash of the shuttle Columbia, roughly a year before the rover landings.

The hills lay a mile and a half (2.5 km) away, and the drive there took about 60 sols. Scientists could only speculate on the hills' origin — debris from a distant crater? Pieces of a buried crater's rim, poking upward through the Gusev plains? No one knew.

Exploring a landscape: European Space Agency's Mars Express

RIGHT LOOKING DOWN on Coprates Chasma, part of Valles Marineris, shows troughs that developed when faulting opened the valley. This HRSC view has north at right and spans about 180 miles. ESA/FU BERLIN, G. NEUKUM

Shortly before reaching the hills, Spirit dug a trench in the soil with one wheel. Its instruments detected magnesium-sulfate salt in the subsurface dirt. Scientists think moisture percolating through the ground, dissolving minerals, and evaporating at the surface could have left the salt behind.

It was just a foretaste. As soon as Spirit drove off the plains into the foothills, it found rocks unlike any seen before at a spot named West Spur — rocks showing ample evidence of salts and other signs of alteration by water.

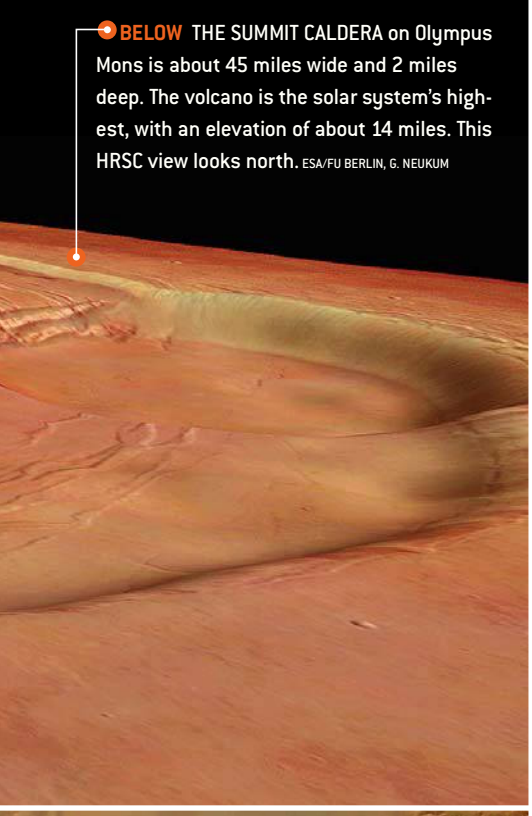
A softball-size rock called Pot of Gold ("the prize at the end of our rainbow," jokes team member Larry Soderblom of the U.S. Geological Survey) astonished scientists with its nodules on the ends of stalks. Says rover project scientist Steve Squyres of Cornell University, "I don't know how these things formed, and they are driving me nuts, to be perfectly honest."

The rover's instruments showed Pot of Gold contains hematite, a clear signal of water. A nearby rock, dubbed Rotten Rock by scientists, looks like a hollowed-out loaf of bread — a tough skin partially enveloping a decayed interior. It, too, has been changed by water.

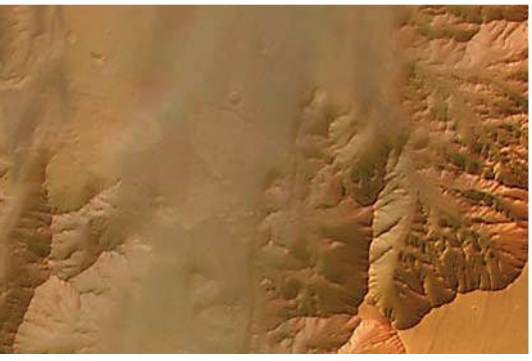
Buoyed by these results — finally, "wet" rocks, after 150 sols in Gusev — rover scientists scrutinized the slope, littered with debris that rolled down from outcrops visible higher up. But Spirit's path was dictated only partly by geology — with the depths of winter approaching, mission controllers were anxious to keep Spirit on north-facing (sunward) slopes to gain extra warmth and solar power. The latter was dwindling steadily as the season advanced into winter and fine, wind-blown dust accumulated on the rover's solar panels.

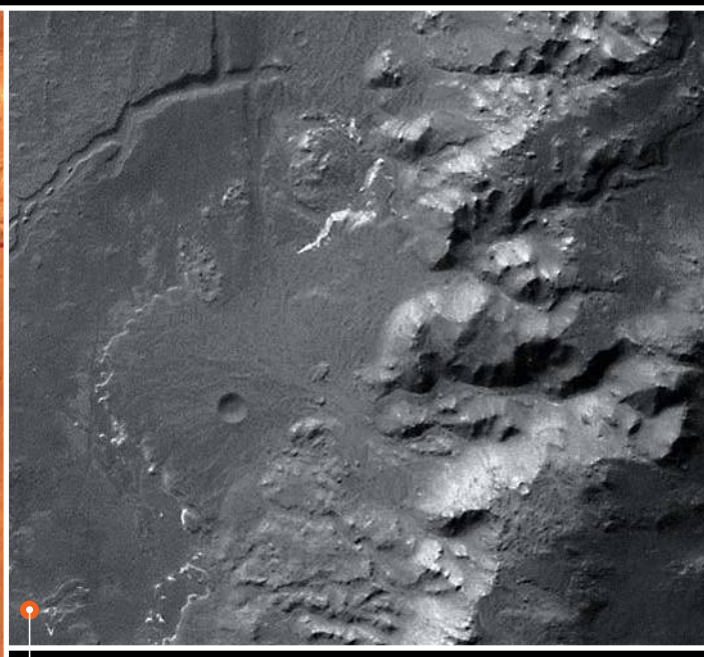
Spirit's findings in the hills told scientists the rocks exposed there are unlike the basalt on the plains below. An outcrop of soft rock called Clovis near the crest of West Spur shows high levels of sulfur, bromine, and chlorine compared to basaltic rocks. Says Squyres, "This is different from the rocks out on the plain, where we saw coatings and veins apparently due to effects of a small amount of water. Here, we have a more thorough, deeper alteration, suggesting much more water."

Other rocks show laminations, hinting they were deposited as sedimentary layers. Tetl, a rock named from a Mayan word for stone, shows alternating layers of coarser and finer particles. Such



BELOW THE SUMMIT CALDERA on Olympus Mons is about 45 miles wide and 2 miles deep. The volcano is the solar system's highest, with an elevation of about 14 miles. This HRSC view looks north. ESA/FU BERLIN, G. NEUKUM





ABOVE DEBRIS THAT FLOWED from the rim of Holden Crater has made an alluvial fan about 12 miles wide at the wall's foot in this HRSC image. ESA/FU BERLIN, G. NEUKUM

LEFT LOOKING LIKE GEOLOGICAL PEANUT BRITTLE, Aureum Chaos is a jumble of terrain that resulted when groundwater flowed away and the land collapsed. The view is about 50 miles wide. ESA/FU BERLIN, G. NEUKUM

layers can form when particles settle in water, volcanic ash falls from the air or surges over the ground, or the wind blows loose sediments around. And two additional rocks, Peace and Alligator, contain more sulfur than any other Gusev rock.

"We haven't seen a single unaltered volcanic rock since we crossed the boundary from the plains into the hills, and I'm beginning to suspect we never will," says Squyres. "All the rocks in the hills have been altered significantly by water. We're having a wonderful time trying to work out exactly what happened here."

How did the water get into the rock? Possibilities include water in volcanic magma before the ash erupted, surface water carrying ash after the eruption, or ground water soaking through the rocks that solidified from the ash.

In the hill country

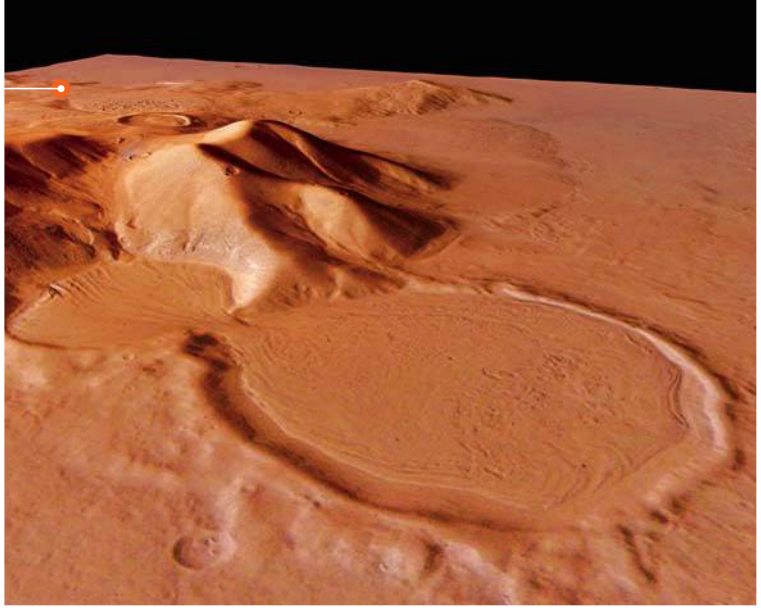
Working its way upward on Husband Hill for 70 sols, Spirit eventually reached a point called Larry's Lookout with a spectacular view over the Gusev plain. Dust devils began to appear as seasonal winds kicked up. Luckily, one dust devil passed right over Spirit in early March, blowing its solar panels cleaner than they had been since about a month after landing. The increased solar power made conducting science experiments on the rocks easier.

At the lookout, a long outcrop caught scientists' attention. Examining it closely, Squyres says, "What we've got is a thick sequence of layered rocks, dipping gently to the northwest."

After mapping it in detail, the scientists decided it was most likely a stack of volcanic debris because it has a uniform chemical composition. "Some of the rocks may have formed by violent eruptions, followed by ashfall from the sky or hot, ground-hugging flows," says Squyres. All, however, appear altered by water, if by varying degrees.

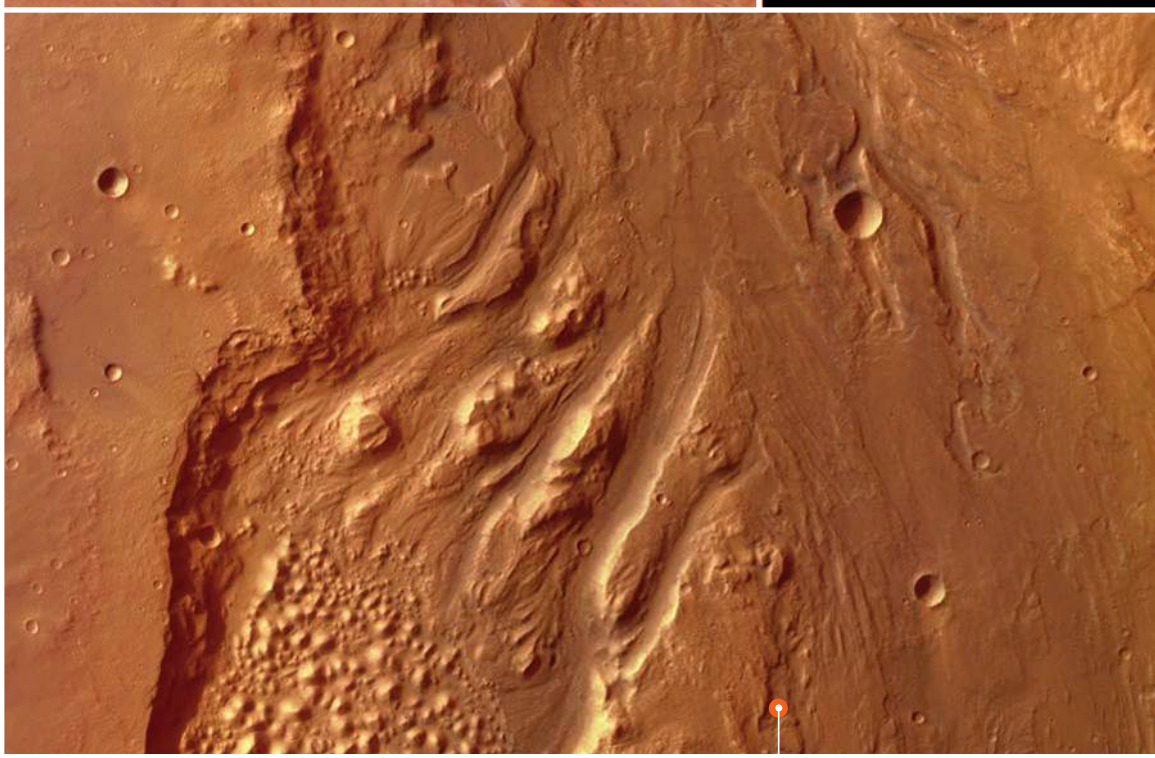
"We're still working out some of the implications of the alteration," says Squyres. "Is the alteration greatest at the bottom of the stack and least at the top, indicating a decrease with time? Or does the alteration also vary laterally, with rocks of the same age that are only tens of meters apart showing very different amounts of alteration?"

Looking ahead, mission controllers are plotting a route toward the south side of Husband Hill. They are driving Spirit around the hill's west side on a spiral path, gaining altitude as it goes.



RIGHT TRACES OF A GLACIER fill two adjacent craters in Promethei Terra at the eastern rim of the Hellas Basin in this perspective view made from HRSC images. Scientists would like to know if there is any ice remaining under the debris filling the craters. The larger crater is about 11 miles across. ESA/FU BERLIN, G. NEUKUM

ABOVE CENTRAL GUSEV CRATER appears in this image from the HRSC imager on Mars Express. The dark patches are the combined streaks of thousands of dust devils. The image is about 37 miles wide. ESA/FU BERLIN, G. NEUKUM



ABOVE GROUNDWATER ESCAPING from Iani Chaos flowed into Ares Vallis and eventually into the northern lowlands. Note the streamlined erosion in this HRSC image. ESA/FU BERLIN, G. NEUKUM

LEFT GIANT LANDSLIDES CASCADED from the flanks of Olympus Mons, creating a steep scarp. Parts of the volcano show uncratered lava flows that may be only a few million years old. The HRSC view is about 100 miles wide. ESA/FU BERLIN, G. NEUKUM

Roving Meridiani's plains

In contrast to Spirit, Opportunity hit paydirt right off. Bouncing to a stop inside 65-foot (20m) Eagle Crater — making the first interplanetary hole-in-one — Opportunity unpacked itself and opened its camera eyes. Astonished scientists found themselves gazing at a foot-high outcrop of layered bedrock, the very thing they'd hoped to find, less than 30 feet (9m) away.

Finding bedrock is crucial for planetary scientists because it records the local geological story wherever it is found. And the mini-cliff outcrop within Eagle Crater proved even more exciting once mission researchers took a close look at it using all of Opportunity's instruments.

They showed the Eagle Crater rock unit is sedimentary, and it was laid down in the shallow water of a briny, acidic sea.

Pieces of another geological puzzle soon fell into place, too. The view from orbit indicated hematite was concentrated all over the landing area, but scientists, looking at rover images, were initially uncertain exactly where it was. At the same time, Opportunity's cameras were recording uncountable numbers of tiny spherules lying everywhere. Project scientists quickly dubbed the spherules "blueberries," thanks to their shape and size, just a few millimeters across.

In one location along the outcrop, Opportunity found blueberries thickly carpeting a hollow. When the rover turned its infrared spectrometer (Mini-TES) onto the hollow, the signature of hematite came booming back.

Mars to scientists: The hematite's in the blueberries.

Geologists identified the blueberries as "concretions," and note they form as water seeps through rock, leaching out iron-bearing minerals and forming spheres and granules. Physically tougher than the surrounding rock, the blueberries are strong evidence of water's action at the Meridiani site.

Opportunity spent more than 60 sols — 2 months — rolling around inside Eagle Crater. It mapped the outcrop, which wraps around roughly half the crater's perimeter, in exquisite detail, capturing the texture of the sedimentary layers in the rock. This revealed interweaving micro-structures only fractions of an inch thick. Such a pattern is called crossbedding, and on the scale seen in the crater, it means the rock particles were laid down in gently flowing water.

Opportunity drilled into the outcrop in dozens of places, using its instruments to analyze the rock's chemical makeup and finding it extremely rich in sulfate minerals. The main rock geologists found is jarosite, an iron-sulfate hydrate.

"Jarosite is a mineral that *requires* water for its formation," says Squyres. "Water once flowed through these rocks. It changed their texture and their chemistry."

And, he adds, "The really cool thing here is that an environment like this would have been suitable for some simple forms of microbial life. That doesn't mean life was there, of course. But we flew this mission because we wanted to find out if Mars ever had habitable environments. And the answer, we now believe, is that it did."

LAYERS OF ICE AND DUST make up the northern polar cap, as seen in this perspective view from HRSC images. The cliffs rise about a mile high, and the dunes in the foreground are likely sand and volcanic ash that have weathered out of the cap. ESA/FU BERLIN, G. NEUKUM

Leaving the nest

After nearly 60 sols of its 90-sol nominal mission, scientists directed Opportunity to drive out of Eagle Crater and head for a much larger and deeper one named Endurance. This crater, the size of a small stadium, lies about half a mile (800m) east of Eagle. It has a diameter of 430 feet (130m) and is more than 65 feet (20m) deep.

Opportunity's first look into Endurance provided one of the mission's most spectacular views. Standing on Endurance's smooth rim, the rover gazed down the crater's inner wall, a 20° slope that drops to a floor with a small field of swirling, sharply wind-sculpted dunes.

Scientists were pleased to count several distinct bedrock layers exposed in the wall. These layers include deeper and older strata than the Eagle Crater unit, which appeared to form the rimrock at Endurance just as it did at Eagle.

Mission controllers surveyed the crater by driving the rover around the rim's southern part. Testing on Earth showed the rover could drive safely down the slope into the crater if it stayed on rock as much as possible. Inching its way slowly from the southwest rim toward the crater bottom, Opportunity stopped to examine methodically and drill into many of the slabs of rock, most of them littered thickly with blueberries.

In all, scientists found five separate strata, some showing the shallow-water crossbedding seen at Eagle. Others, however, show smoother laminations that hint they were dunes before being inundated and compacted into soft rock.

"If there's a change in rock type, there was a change in environment," says Squyres. "We want to get to the contact between units to see how the environment changed. Is it gradual? Or abrupt?"

The rover found transitions between strata are sharp and distinct, and rocks at lower levels — older rocks — were chemically altered by water to a greater extent. In the crater's bottom, the rover met with soft, basalt sand, and mission controllers and scientists abandoned the idea of exploring the small dune field because they feared Opportunity would get stuck.

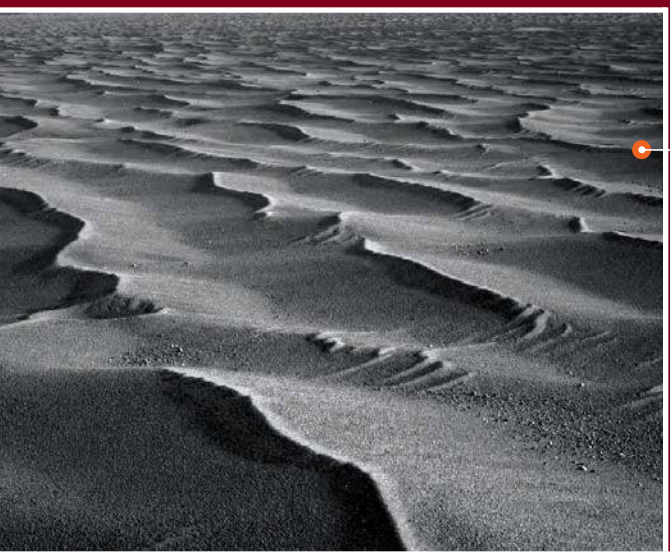
Freed from that danger and feeling increasingly sure of their rover-handling skills, mission controllers drove Opportunity to the foot of Burns Cliff, a steep feature on the crater's south rim. The cliff exposes a section of layered rocks about 30 feet (10m) high. With the rover parked on a north-facing slope tilted more than 30°, project scientists acknowledged they were pushing the vehicle to the edge of its capabilities.

Says Squyres, "In the lower portion of the cliff, the layers show strong indications that they were last transported by wind, not by water like some layers higher up. The combination suggests that this was not a deep-water environment but more of a salt flat, alternately wet and dry."

Heat shield

After 181 sols inside Endurance, mission scientists decided it was time for Opportunity to hit the road. Driving out where it

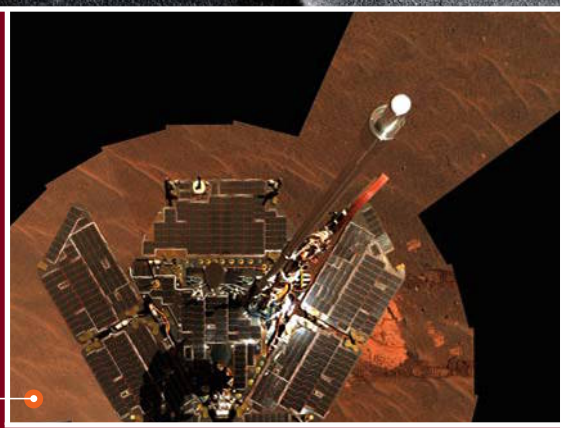
In a vastness of rock and dune: NASA's rover Opportunity on Meridiani Planum



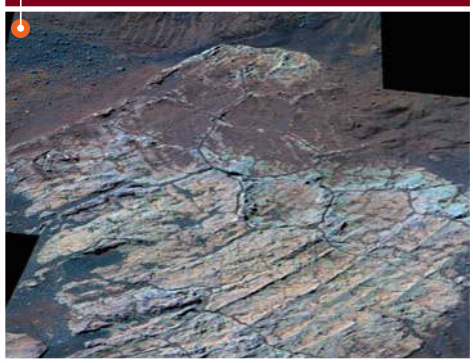
LEFT A sea of foot-high dunes forms a landscape eerily like parts of Earth. NASA/JPL/CORNELL

RIGHT The course ahead. Opportunity is driving toward the light-colored Etched Terrain and Victoria Crater at bottom, which scientists hope will give them a look at more bedrock layers and additional eras in martian history. NASA/JPL/MSSS

BELOW ONE OF THE ROCK SLABS inside Endurance, Escher rock showed cracks in its surface resembling mudcracks. Scientists are unclear if the cracking occurred when the rock formed or after being soaked again. NASA/JPL/CORNELL

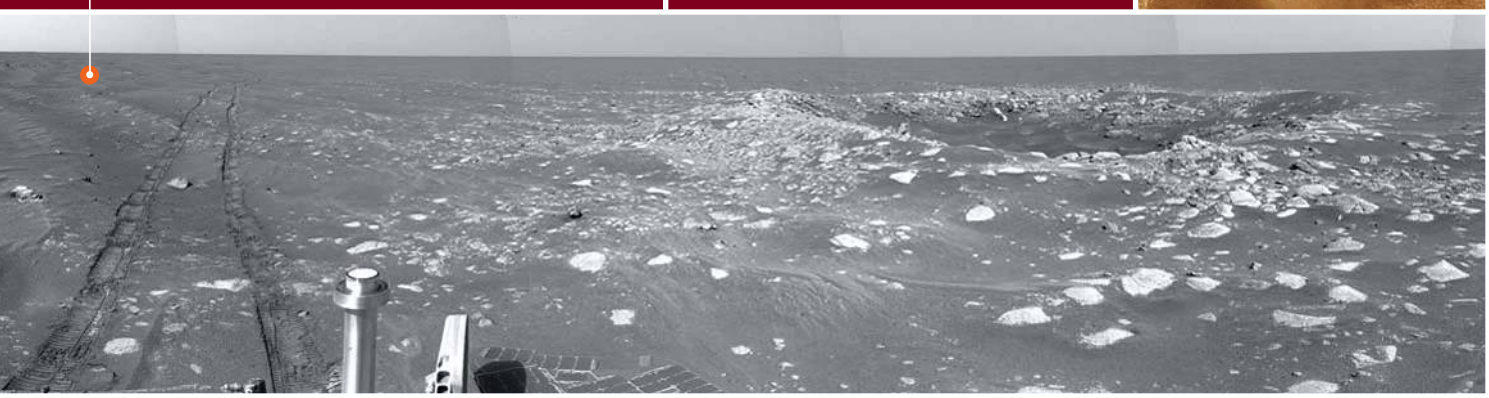


ABOVE Opportunity's self-portrait shows a rover with clean solar panels — compare with Spirit on page 17. Meridiani Planum is darker and less dusty than Gusev Crater. The spherules on the ground are the ubiquitous hematite-rich "blueberries." They formed when the Meridiani rock was soaked in briny water, and then they weathered out. NASA/JPL/CORNELL



ABOVE An extraterrestrial first, this nickel-iron meteorite was found by Opportunity not far from the heat shield. The meteorite is about the size of a volleyball. NASA/JPL/CORNELL

BELOW After passing Viking Crater, Opportunity's cameras show little to steer by around the horizon. NASA/JPL/CORNELL



entered the crater, at a site dubbed Karatepe, the rover re-emerged onto the Meridiani plain.

About 500 feet (150m) south lie the ruins of the spacecraft's heat shield, discarded during Opportunity's descent and landing. The shield hit the ground at about 200 mph (320 km/h), leaving a shallow crater in the ground and popping inside out. Engineers hoped to examine the wreckage to assess how well their design had worked, but they found the charred heat-shield surface was on the inside and not easily visible.

Then, on sol 339 (January 5, 2005), came a surprise — a meteorite, the first ever discovered on another planet. The volleyball-size "rock" was a pitted lump sitting on the surface, and the rover's instruments quickly discovered it is metallic — a nickel-iron meteorite, in fact. How long it has sat there is unknown.

As the heat shield and rim of Endurance Crater dwindled in the rearview mirror, scientists kept Opportunity headed south. Their goal was an area called the Etched Terrain, which lies about 3 miles (5 km) south of Endurance. The terrain's nature is known only from orbital views, which suggest it is a wilderness of low, light-colored rock outcrops.

"This is a journey into the unknown, to something completely new," says Squyres. Perhaps a dozen small craters about the size of Eagle Crater stand as navigational checkpoints for mission controllers.

And Opportunity's drivers back on Earth needed them. Meridiani Planum could easily serve as the prototypical "trackless waste" geographers write about. It offers no prominent features and no obvious, faraway landmarks to steer a course by.

When the rim of Endurance dropped below the horizon, the view in every direction became essentially identical. And with its camera eyes just 5 feet (1.5m) above the ground, Opportunity's horizon lies only about half a mile (1 km) away.

INSIDE ENDURANCE, Opportunity found the going generally good, except for a small dune field. The rover was able to examine numerous water-altered rocks, including Wopmay in the right foreground. At rear stands Burns Cliff. NASA/JPL/CORNELL

Whatcha dune?

Opportunity passed a series of small craters named for famous exploring ships (and spaceships) — Argo, Alvin, Jason, Investigator, Géographe, Naturaliste, Vostok, Viking, Voyager, and others. These craters all resemble Eagle in being shallow dimples in the ground that expose a few inches or a foot of the rock unit found in Eagle Crater.

Rippling across the plains are long lines of dunes made of coarse sand and covered with the ubiquitous blueberries. The dune ripples rise only a few inches to a foot, and Opportunity rolled easily up and over all of them, making record time as it continued its southward course.

That was until sol 446 — or, as it was on Earth, April 26, 2005. On that day, Opportunity met a dune its wheels didn't conquer. Instead, they churned into the foot-high dune, began to slip, and the rover became stuck.

Lab tests showed the best approach was driving in reverse to back out of the soft dune. But progress was painfully slow — every inch of travel took over 8 feet of wheel rotation, in an effort-to-results ratio of 200 to 1.

Finally, June 4, 2005, Opportunity got back on firm ground. Mission controllers directed the rover to perform a classic driver's-ed three-point turn. This placed the rover's front end, with the instrument arm, where it could examine the treacherous spot. (When it became stuck, Opportunity was driving in reverse, a tactic used to keep wheel lubricants flowing smoothly.)

The sand trap was promptly dubbed Purgatory Dune.

Far horizons

Free of the clingy dune, Opportunity's heading remains south. "This little incident is not going to deter us from continuing our southward exploration," says Squyres. "South is where we think the best science is, and we're not going to turn tail and run because of one unfortunate episode."

Ahead lie two heavily eroded craters, Terra Nova and, nestled within it, Erebus. Orbital views hint the two have subdued walls — each appears to be barely a ring of rocks.

Scientists want to study the Etched Terrain bedrock in detail. What can its outcrops tell about other eras and environments in martian history? How do these rocks relate to the stratigraphic sequences seen in Eagle and Endurance — are they above (younger) or below (older)? Or are they just more of the same unit that forms the local surface around Eagle and Endurance?

Beyond stands Victoria Crater, 5 times wider and deeper than Endurance. It lies on the far side of the Etched Terrain, and getting there requires Opportunity's controllers to find a safe route through the terrain — or a path around it.

Once at Victoria, scientists will study the crater from the rim, as they did at Endurance, mapping its slopes and surveying its rock exposures. Then come the important questions and decisions. Is there a route down the inside wall? And once inside, can Opportunity get out again?

Like Spirit, Opportunity has performed so well and exceeded its design lifetime by so much that it seems greedy — or even to court disaster — to think about what might follow Victoria Crater.

But why should Opportunity's mission end there? Vast tracts of unexplored terrain — an entire planet as spacious as the land areas of Earth — still lie ahead of both rovers. With the passing of local winter, the days are lengthening and warming, even if Mars is approaching a season notorious for dust storms.

It's not clear how long Spirit and Opportunity will survive — either could die at any point through mechanical or electronic failure. Or the steady buildup of dust on their solar cells could reduce power below the survival point.

But as long as Earth-built wheels can leave tracks on Mars, the rovers' mission will continue. And who can say? Perhaps their greatest discoveries still lie ahead.

Robert Burnham *is a senior editor of* Astronomy.

IRREGULAR GALAXIES, like NGC 6822 in Sagittarius, don't fit into any normal galaxy class. Even as a member of this group, NGC 6822 stands out. A faint arm of young, blue stars arcs away from the galaxy's boxy main body, and an unusual number of bright ionized-hydrogen clouds (here shown as purple) pepper the tiny galaxy. Both features point to significant star formation. NGC 6822 is located only about 1.6 million light-years away. A member of the Local Group, which includes the Milky Way, NGC 6822 was discovered by E. E. Barnard in the early 1880s. In 1925, Edwin Hubble conducted the first detailed investigation of the galaxy at Mount Wilson Observatory.

NOAO/LOCAL GROUP GALAXIES SURVEY TEAM

Just 85 years ago, astronomers realized our home galaxy is only one among billions. They've been trying to make sense of galactic variety ever since.

/// BY CHRISTOPHER J. CONSELICE

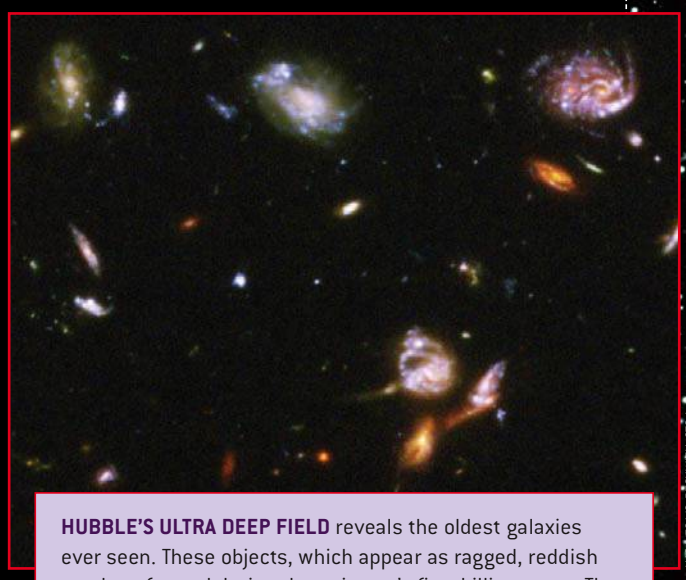
{ EXTRAGALACTIC ASTRONOMY }

AN EMBARRASSMENT of GALAXIES

GALAXIES, LIKE PEOPLE, COME IN ALL SHAPES AND SIZES. This was obvious to astronomers even before they knew what galaxies really were — "island universes" teeming with stars, planets, gas, and dust, separated from our own galaxy by a vast gulf of space. Today, astronomers understand these differences exist because, like people, galaxies have different histories: What they've experienced affects how they look.

CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM

THE GRAND SPIRAL M101 is the type of object the word "galaxy" conjures. M101 lies about 25 million light-years away in Ursa Major and presents itself nearly face-on to our view. Blue knots show where clusters of massive, young stars reside; pink regions highlight where star formation is taking place. The spiral arms of our own galaxy are wound tighter.



NASA/ESA/S. BECKWITH, STScI

HUBBLE'S ULTRA DEEP FIELD reveals the oldest galaxies ever seen. These objects, which appear as ragged, reddish patches, formed during the universe's first billion years. The Hubble Space Telescope stared at the same spot in space for nearly 3 months, collecting some 800 visible-light and 400 infrared images.

GIANT ELLIPTICAL NGC 5128 is at least 3 times as wide as our Milky Way. It got this way by ingesting smaller galaxies. The enigmatic lane of dust and young, blue stars is one reason astronomers consider the galaxy peculiar. NGC 5128 lies 13 million light-years from Earth; it's known also as Centaurus A, one of the sky's brightest sources at radio wavelengths. *Inset:* Last year, astronomers imaged NGC 5128's warm dust using the Spitzer Space Telescope and revealed a tangled, twisted sheet of dust that's likely the remains of a spiral galaxy torn apart some 200 million years ago. ESO; INSET: NASA/JPL/CALTECH, J. KEENE

Many interesting and exotic galaxies lie nearby. Some are majestic spirals like our own Milky Way; others are calm, featureless, giant ellipticals, while still others appear highly distorted. Astronomers have learned much about galaxies by studying the details that make one object different from another.

This is, in fact, the oldest way of looking at galaxies. During the 19th century, observations with large telescopes gave astronomers their first glimpses of basic galactic properties. Early observers saw galaxies only as faint, diffuse objects and classed them as galactic nebulae, lumping them together with other telescopically diffuse objects, like unresolved star clusters and gas clouds in our own galaxy. Astronomers soon discovered these objects are scattered across the sky, but their true nature still was unclear.

Christopher J. Conselice *is an astronomer at the California Institute of Technology in Pasadena.*

Imaging technology dramatically changed our understanding of galaxies. Now, thanks to the Hubble Space Telescope (HST) and other new instruments, the comparison of galaxy structure is taking another giant leap forward. Our increased knowledge of these systems helps new ideas emerge for explaining galaxy populations.

Hubble tunes in

The 1920s work of Edwin Hubble at California's Mount Wilson Observatory finally convinced astronomers galactic nebulae lie outside our Milky Way. Hubble created an influential classification system for galaxies that forms the basis of those used today. But while his system is fundamental to our current understanding of galaxies, it's an incomplete look at the nearby galactic population.

To be fair, Hubble could study only nearby, bright systems — those easiest to observe with early 20th-century technology. All the galaxies he compared were in roughly the same evolutionary state, and his system could not take into account effects astronomers now consider important for understanding a galaxy's life.

Hubble's major contribution was to classify galaxies into two broad types: ellipticals and spirals. Elliptical galaxies are oval and largely featureless, while spirals are flattened disks displaying a set of arms winding around a central bulge. Hubble also found that spirals come in two flavors — those with central bars extending from the bulge to the arms, and those without.

Hubble envisioned his classification scheme as a tuning fork. Ellipticals on the left side formed a base from which emerged two branches populated with two types of spirals — barred and unbarred. He further divided each spiral class based on the tightness of its spiral arms and the

relative brightness of its central bulge. An "early type" spiral, in Hubble's parlance, was one closer to the ellipticals on the tuning fork, with a large central bulge, while "later" types were increasingly dominated by the disk component.

Rising complexity

In the decades following Hubble's introduction of the tuning-fork scheme, observations revealed an abundant variety of galactic structure that cried out for a more complete classification system. Considering appendages, for instance, a large dog and a small horse look similar. Sufficiently detailed observation, however, tells a different story.

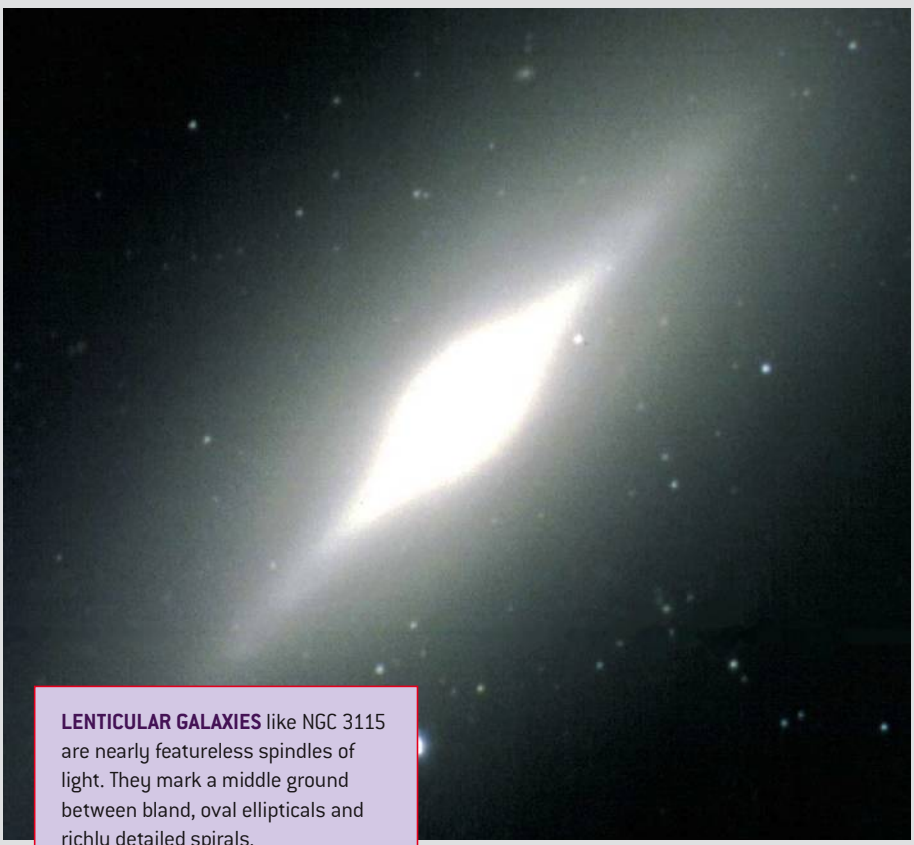
Astronomers faced a similar problem: The more they knew about galaxies, the more new systems for grouping them became necessary. In the late 1950s, University of Texas at Austin astronomer Gerald de Vaucouleurs devised a system that remains the most widely used today. He argued galaxies should be classed by observable structures such as rings, bars, and other internal features.

The astronomer revised and extended Hubble's two-dimensional tuning fork into a complex lemon-shape volume. In essence, de Vaucouleurs gave the tuning fork's base a half twist, creating room for a broader range of ring-shape and spiral-shape features (see "Organizing galaxies" on page 33).

Other classification and morphology systems have looked at different parameters. Some have been based on how galaxies distribute their light. William Morgan of the University of Chicago's Yerkes Observatory based his 1958 system in part on how much of a galaxy's light is concentrated toward its center. He found that galaxies with centrally concentrated light usually contain older stars, while diffuse galaxies tend to have younger stars.

CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/CFHT/LUM

DWARF IRREGULAR GALAXY NGC 3109 lies 4 million light-years away in Hydra. Galaxies like this are gas rich but make stars slowly.



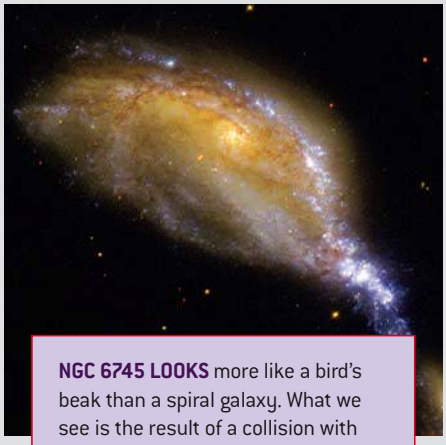
NOAO/AURA/NSF

LENTICULAR GALAXIES like NGC 3115 are nearly featureless spindles of light. They mark a middle ground between bland, oval ellipticals and richly detailed spirals.

Ellipticals, which display the most concentrated light, contain older and more evolved stars, while spirals, which spread their light across a broad disk, are populated with younger stars. This important realization ties an easily observed feature — light distribution — to a galaxy's mix of stars.

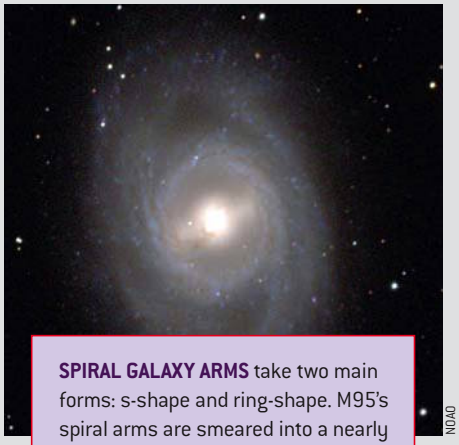
To place galaxies into similar populations, astronomers must understand the role visible features play in galactic evolution. Are galaxy structures caused by gravity — such as spiral arms and rings — critical components? How do different kinds of stars or different ratios of gas and dust drive what happens in a galaxy? Are these even the major features astronomers should use when classifying galaxies? All these questions bear on aspects of current research, and so far, there are no simple answers.

A galaxy's most obvious feature is its starlight, so understanding galactic evolution requires detailed knowledge of stars and the gas and dust that form them. Observations at radio wavelengths tell us some galaxies hold much gas in



NASA/HUBBLE HERITAGE TEAM/ROGER LYNDS ET AL.

NGC 6745 LOOKS more like a bird's beak than a spiral galaxy. What we see is the result of a collision with another galaxy out of the picture just below the "beak's" tip. The cosmic crash set off a wave of star formation that arcs NGC 6745's length.



NOAO

SPIRAL GALAXY ARMS take two main forms: s-shape and ring-shape. M95's spiral arms are smeared into a nearly continuous ring around its central nucleus. The galaxy's other obvious characteristic is its bright stellar bar that extends from the central disk.

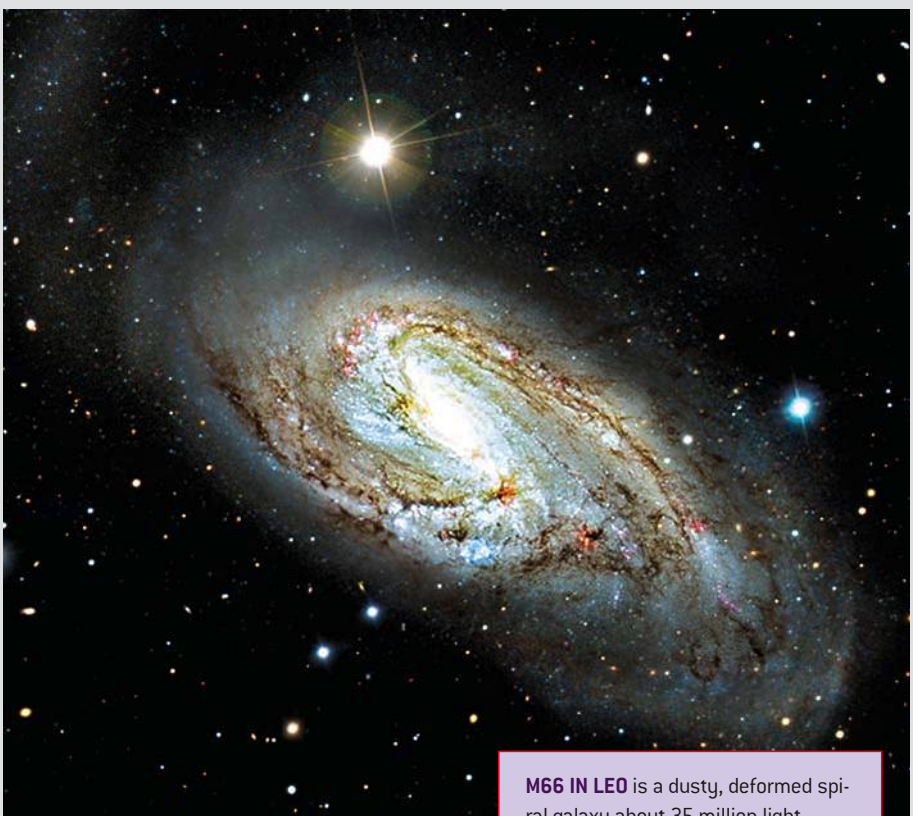
CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM

M87'S STARS number in the trillions. This giant elliptical galaxy lies at the heart of the Virgo galaxy cluster, some 60 million light-years away. M87 has 14,000 globular clusters and a central black hole that spews a jet of gas thousands of light-years.

various forms. And we often see dust in spiral galaxies, particularly those appearing edge-on to our line of sight.

But a galaxy is much more than the sum of these parts. We do not know what makes up 90 percent of the mass of galaxies we observe. Astronomers have nicknamed this unknown component "dark matter," and its influence on both galaxy formation and galactic structure is almost unknown. Until we know dark matter's role, we can't be sure the conclusions we develop based on our observations are valid. Yet, the diversity we do see suggests we can learn a lot about galaxies from the small fraction that reveals itself to us through starlight.

Astronomers began detecting small, faint, low-mass galaxies in the 1930s, soon after Hubble published his galaxy classification system. Dwarf galaxies just didn't fit in. Because Hubble used only nearby, bright galaxies in his scheme, the tuning fork couldn't accommodate anything but the biggest and brightest systems.



CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM

M66 IN LEO is a dusty, deformed spiral galaxy about 35 million light-years away. Tides raised by neighboring galaxy M65 are responsible for M66's distorted arms.

Giant ellipticals and tiny dwarfs

Now, we know dwarf galaxies are different from the large, bright objects Hubble classified. This wouldn't be too much of a problem if these galaxies were rare, but unfortunately, they're the most common galaxy type in the universe. Worse yet, dwarf galaxies have a low density of stars, which makes them hard to locate and identify.

The Local Group, the galaxy group to which the Milky Way, the Andromeda Galaxy (M31), and the Large and Small Magellanic Clouds belong, is dominated by dwarf systems. Of the roughly 45 galaxies known or suspected to lie within the Local Group, all but five are dwarfs. And dwarfs make up an even greater proportion in dense galaxy clusters, where giant galaxies are surrounded by up to 10 times the number of dwarfs as in our Local Group.

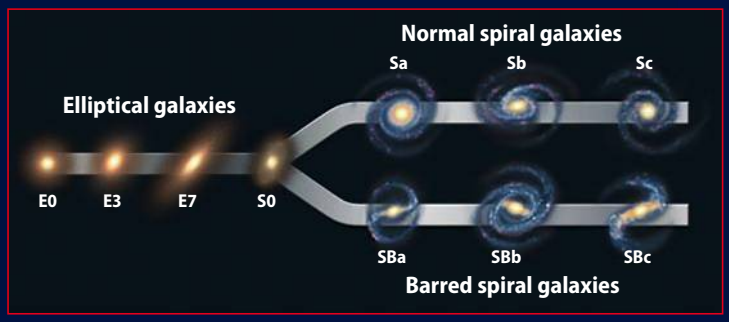
Why so many dwarfs exist is a question actively being investigated. Many astronomers suspect their presence is a clue to processes leading to the formation of larger galaxies.

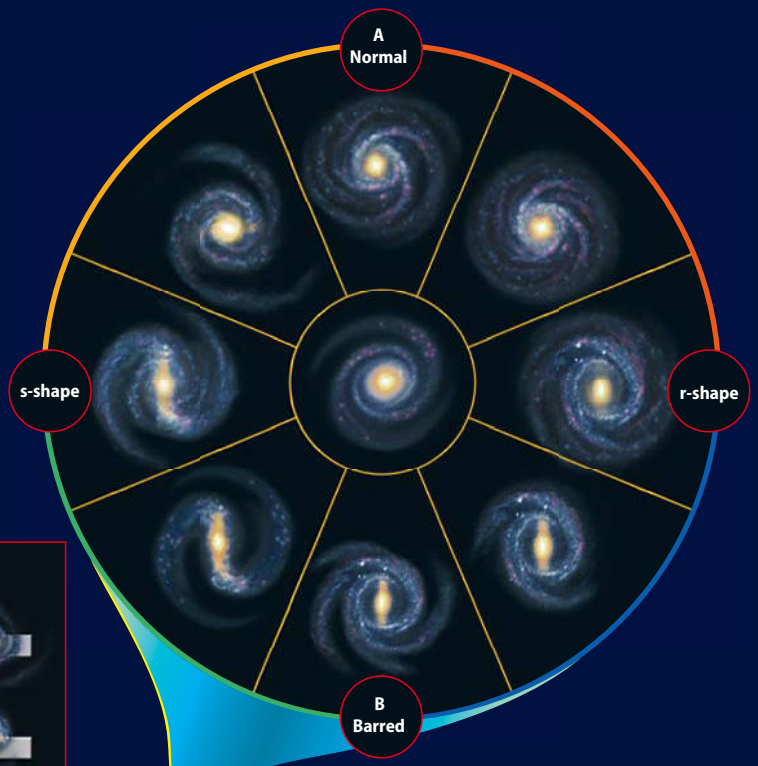
By the 1970s, astronomers realized many large yet faint galaxies are peppered throughout the universe. Although some are among the largest galaxies known, these low-surface-brightness

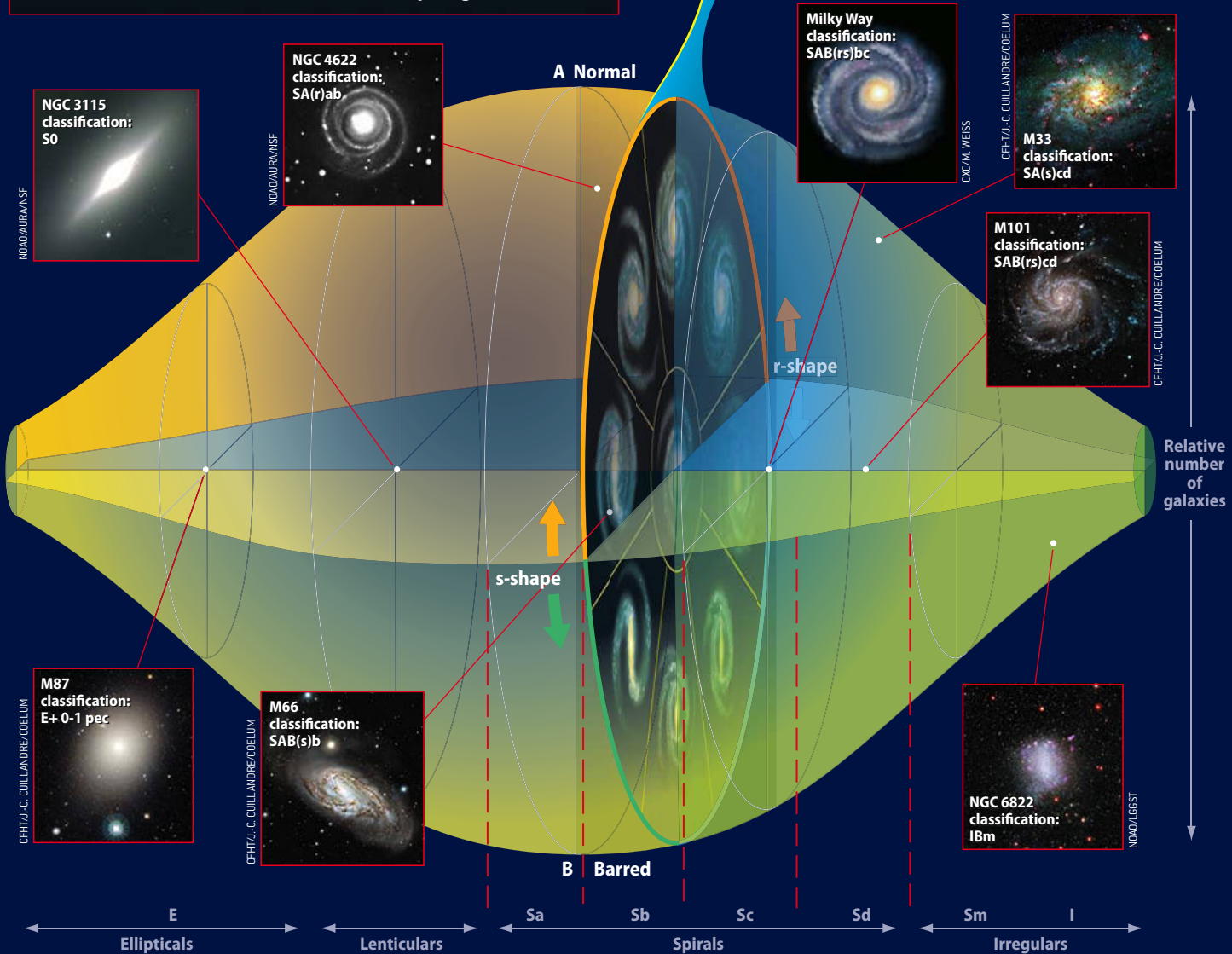
Organizing galaxies

Giving Hubble's tuning fork (inset, below) a half twist creates the lemon-shape "classification volume" developed by Gerald de Vaucouleurs in the late 1950s. Normal galaxies occupy the top half, barred galaxies go on the bottom, and different classes and subclasses line up horizontally, from ellipticals on the left to irregulars on the right.

The lemon's height and shape reflect the relative number of galaxies in the sample de Vaucouleurs examined. Slicing into the lemon (right) reveals a wheel of galaxy shapes controlled by the presence or absence of a central bar and the degree to which arms appear s- or ring-shape. Galaxies with unusual properties are classed as "pec," for peculiar. Astronomers seek a more complete scheme based on observed galactic properties.







ASTRONOMY: KELLIE JAEGER

GALAXIES INTERACTED more often when the universe was young, but groups like Stephan's Quintet in Pegasus show the process continues today. NGC 7320, the galaxy at top center peppered with pink star-forming regions, lies in the foreground and is about 8 times closer than the interacting members of the cluster. The other spirals, which assume distorted shapes thanks to one another's gravity, lie nearly 300 million light-years away.

GEMINI OBSERVATORY/TRAVIS RECTOR, UNIVERSITY OF ALASKA AT ANCHORAGE

objects weren't seen in astronomical surveys simply because they have such a low density of stars.

At about the same time, astronomers noticed a new type of large, bright, and massive galaxy residing in the centers of galaxy clusters. Their masses often exceed those of normal elliptical galaxies by 100 times or more. While these objects sometimes look like ellipticals, internal features make it clear they're different. These galaxies are probably still forming, cannibalizing smaller ones that stray near.

Astronomers are seeking a new classification system to understand the full diversity of galaxies and their properties. It's a system that does not exist yet, but new observations are giving astronomers an idea of what galactic features it should include.

Deep fields

In the last decade, the Hubble Space Telescope has triggered a revolution in our understanding of distant galaxies. With Hubble, astronomers can observe how galaxies looked more than 10 billion years ago at the same level of detail most ground-based telescopes manage only for nearby galaxies. So, we can make direct comparisons between the structures we see in distant, young galaxies and those we see in nearby galaxies today. Also, we can learn how galaxies evolve by comparing how these features have changed through time.

Studying young galaxies in this manner requires the deepest observations HST has ever made. In December 1995, HST observed the same part of the northern sky for more than a week — the original Hubble Deep Field. In 1998, the telescope made a similar deep observation of the southern sky, which is called the Hubble Deep Field South. (The original Deep Field was then renamed Hubble Deep Field North [HDFN].)

Then, in 2002, astronauts installed Hubble's new camera, the Advanced Camera for Surveys (ACS). It is more sensitive than any of the telescope's previous cameras and

NOAO/AURA/NSF

THE HELIX GALAXY (NGC 2685) in Ursa Major has an unusual set of filaments arcing perpendicular to its disk. These "polar rings" are likely the shredded remains of a smaller galaxy that merged with the Helix. The rings, which contain stars, gas, and dust, may survive for tens of millions of years.

has a wider field of view. Using ACS, astronomers made the deepest-ever images with Hubble — the Ultra Deep Field.

Taken together, the deep-field images contain thousands of galaxies, capturing them as they looked when the universe was only a few billion years old.

The HDFN proved galaxies have changed dramatically over the universe's life. It's immediately obvious that young galaxies in these images look different from nearby galaxies seen at an age closer to our Milky Way's. Most distant galaxies are distorted or peculiar and don't resemble the spirals and ellipticals so common around us.

Merger mania

Shortly after the HDFN images were taken, a group led by Piero Madau of the Space Telescope Science Institute in Baltimore investigated the star-formation rate in these galaxies. The scientists wanted to know how many stars were created during a given time span, and they discovered galaxies in the past formed stars faster than those in the nearby universe.

Some of these newborn stars are so bright they make the galaxies hosting them gleam brighter than those nearby. Why star formation was more common in the past is still being debated, but the fact that the early universe vigorously made stars is one reason distant galaxies look different.

We also know galaxies in the past interacted and merged more frequently. As one might imagine, when two galaxies merge, their structures become highly distorted. We see this occasionally closer to home, but in the distant past, far more galaxies were merging. In the nearby universe, only about 2 percent of galaxies are merging, while 10 billion years ago, the number was probably closer to 60 percent.

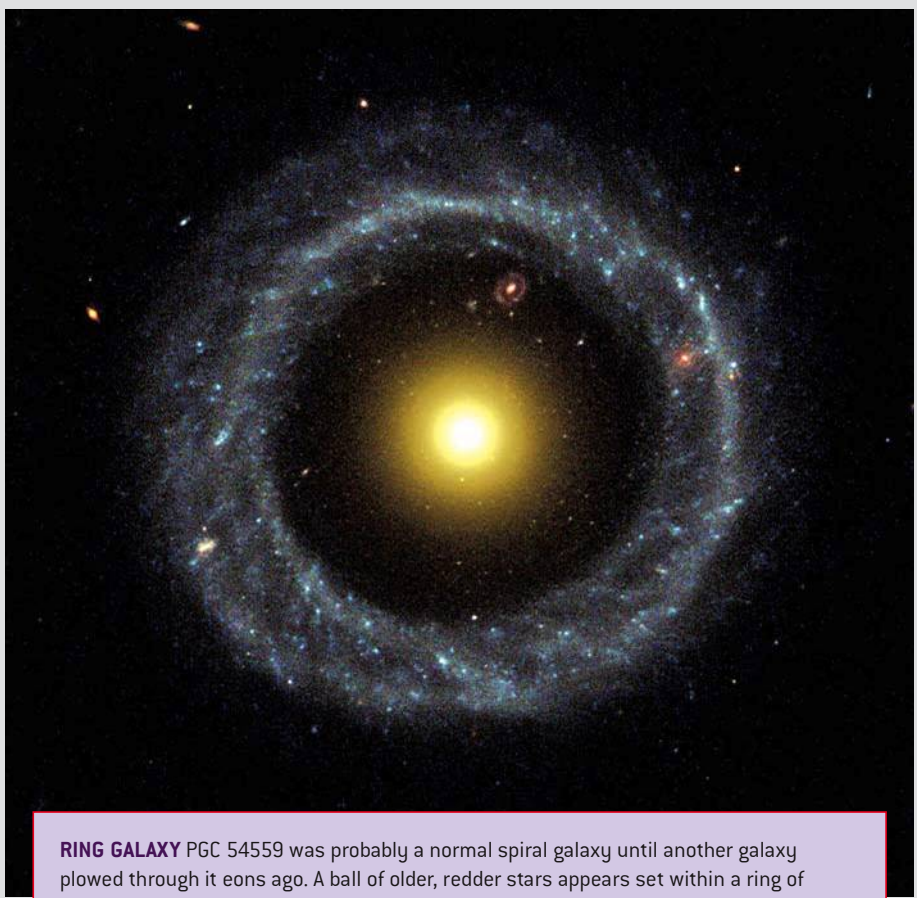
One reason astronomers see more mergers among distant galaxies is the universe's expansion. Galaxies in the past were closer to each other, thus more likely to merge. As the universe expanded, the density of galaxies dropped, and so did the merger rate.

Many galaxy-formation theories predict large galaxies formed from such mergers. Soon after the Big Bang, a vast number of low-mass galaxies formed in relatively crowded environments. Shortly thereafter, they began to merge, producing ever larger galaxies. Today, we see the result of these past interactions when we look in the nearby universe at rich galaxy clusters. These regions contain thousands of galaxies and also harbor galaxies with the greatest masses.

Because galaxy mergers and star formation occurred at higher rates in the past, and because most galaxies in the nearby universe cannot be placed into the Hubble tuning fork, astronomers need new ideas for organizing galaxy types. Recent work suggests no single parameter can distinguish between galaxies of different types as the Hubble tuning fork was designed to do.

Galaxies undergoing much star formation appear bright with many lumpy star-forming regions. On the other hand, galaxies with little or no star formation look smooth, like familiar elliptical galaxies. Star formation and galaxy mergers are critical processes driving galaxy evolution, and features resulting from them probably are among those astronomers will include in a future classification scheme.

It's an exciting time for those studying galaxies beyond our own. Astronomers don't get the opportunity to organize the cosmos very often.

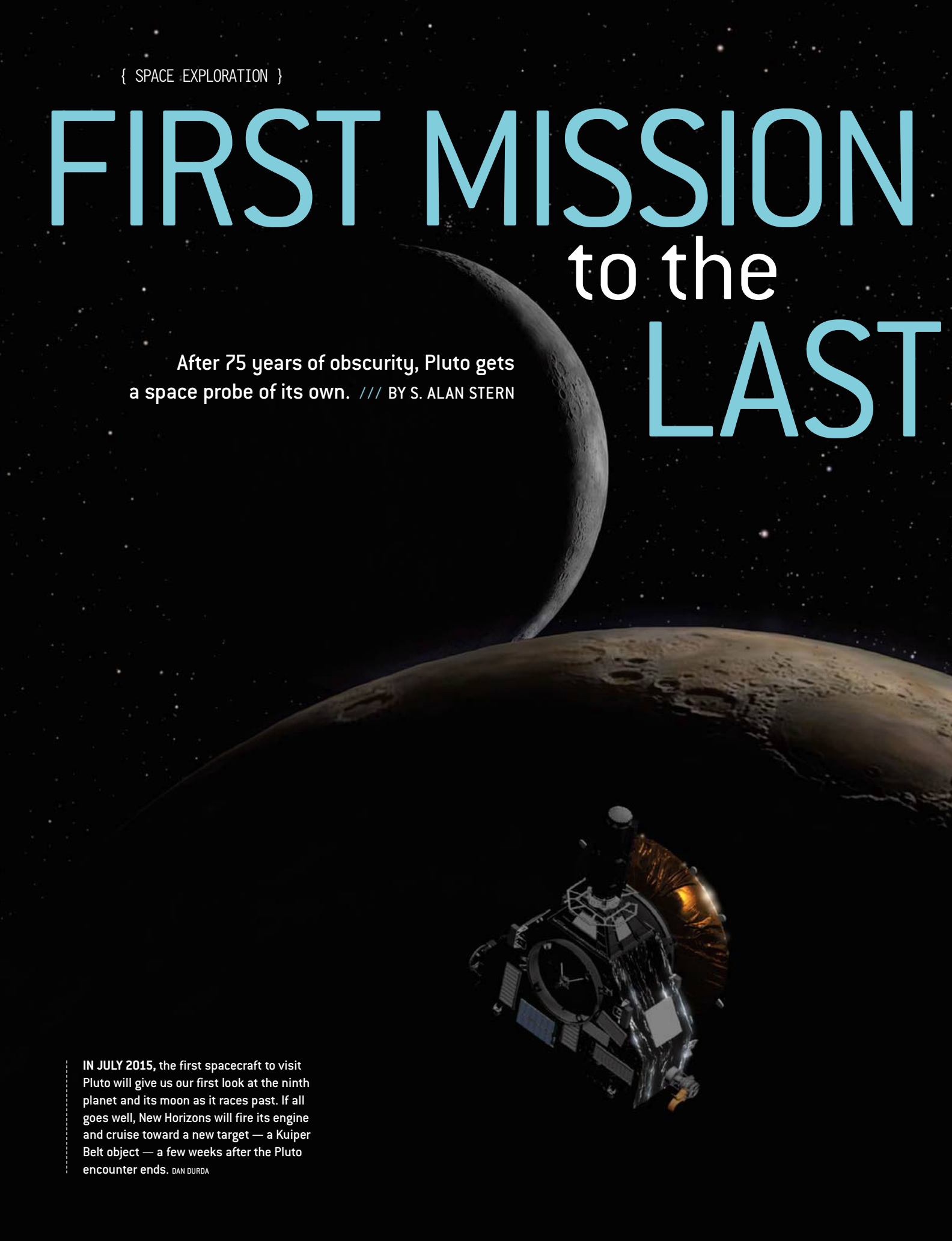


NASA/R. LUCAS, STScI/HUBBLE HERITAGE TEAM

RING GALAXY PGC 54559 was probably a normal spiral galaxy until another galaxy plowed through it eons ago. A ball of older, redder stars appears set within a ring of bright, blue — and thus relatively young — stars, with nothing in between. It spans about 100,000 light-years and lies some 600 million light-years away in Serpens. Look closely at the gap — another ring galaxy appears in the distance.

FIRST MISSION to the LAST

After 75 years of obscurity, Pluto gets a space probe of its own. /// BY S. ALAN STERN



IN JULY 2015, the first spacecraft to visit Pluto will give us our first look at the ninth planet and its moon as it races past. If all goes well, New Horizons will fire its engine and cruise toward a new target — a Kuiper Belt object — a few weeks after the Pluto encounter ends. DAN DURDA

PLANET

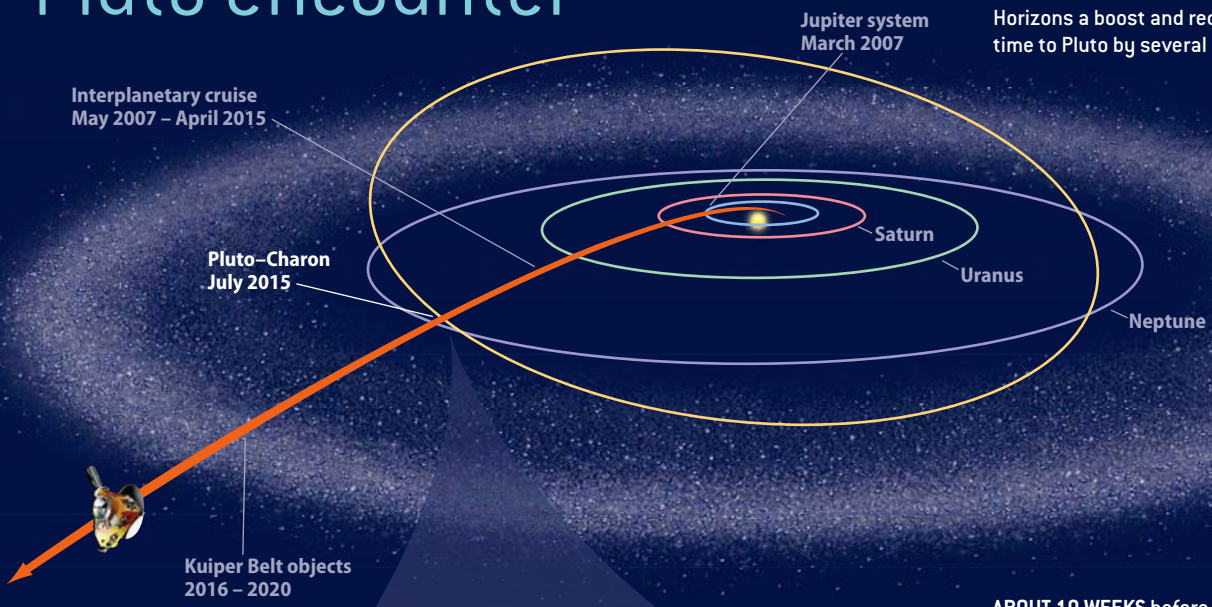
IF ALL GOES WELL IN JANUARY 2006, a spacecraft called New Horizons will rocket into space and begin a decade-long trek to Pluto and its moon, Charon. New Horizons will race across the entire span of the solar system in record time, sweep past Pluto in 2015, and then, hopefully, go on deeper into the frigid darkness to encounter objects that reside in the mysterious Kuiper Belt, which lies at the planetary system's edge.

The National Academy of Sciences ranked exploration of Pluto and the Kuiper Belt as the highest priority mission to begin this decade. Why? Simply put, study of Pluto and its Kuiper Belt cousins is our best bet for obtaining major new insights into the origin and evolution of our solar system, the nature of binary planets, and the workings of the solar system beyond Neptune.

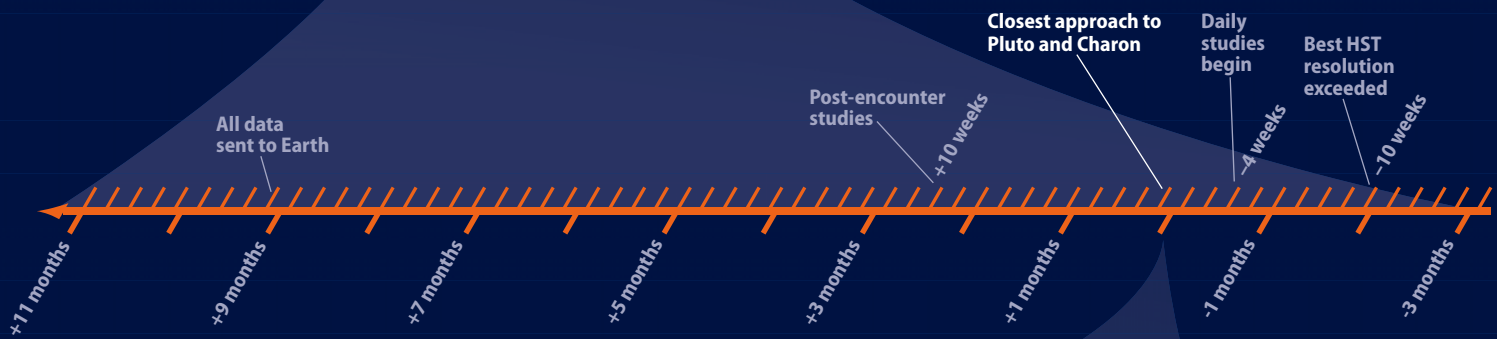
In 1930, when astronomer Clyde Tombaugh discovered the planet Pluto, no one could have guessed how unusual this little world would turn out to be. Over the next several decades, however, planetary scientists found it to be the first planet discovered that has a moon nearly its own size. Scientists also learned that Pluto has complex seasons, a chaotic orbit, an atmosphere that freezes onto the surface every orbit, and a surface coated by fresh snows of frozen methane, nitrogen, and carbon monoxide.

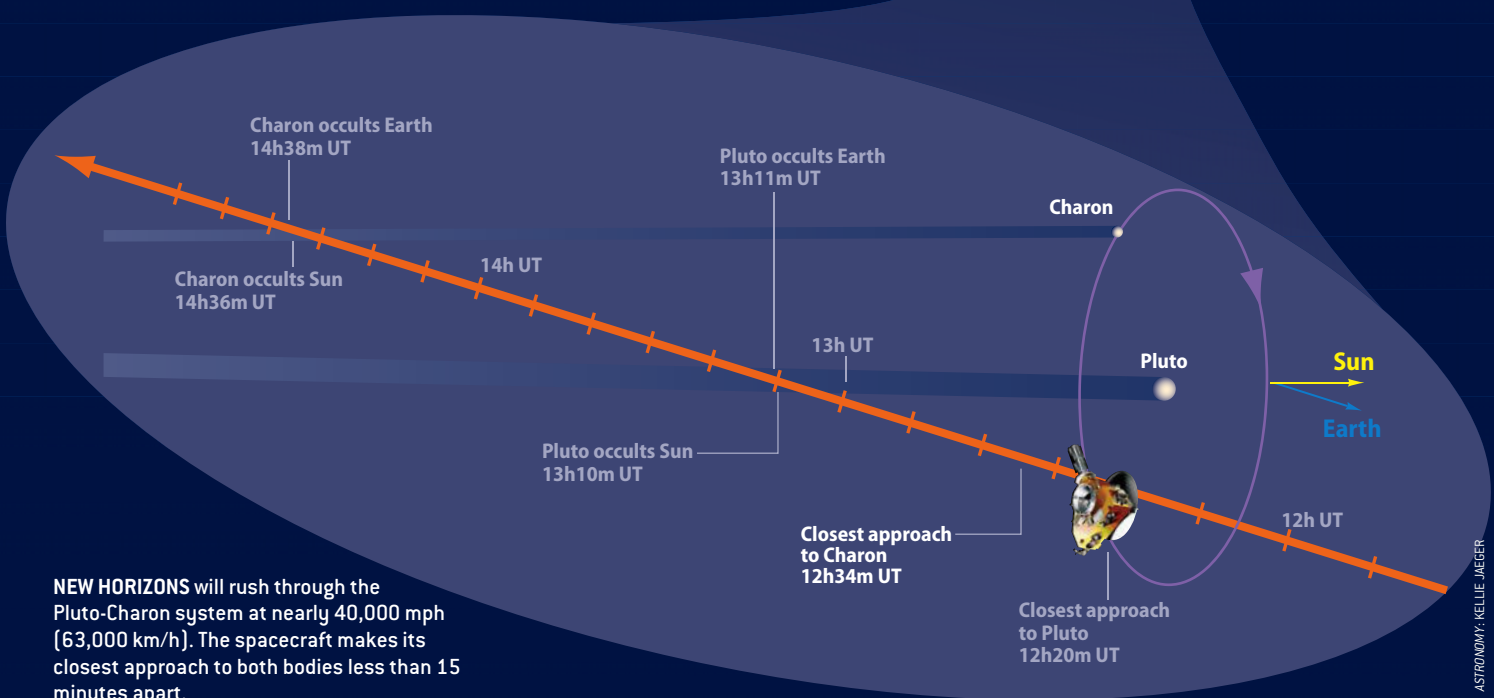
Pluto encounter

A SWING PAST JUPITER in 2007 will give New Horizons a boost and reduce the probe's travel time to Pluto by several years.



ABOUT 10 WEEKS before closest approach, New Horizons' images of Pluto and Charon will be sharper than any from the Hubble Space Telescope.





NEW HORIZONS will rush through the Pluto-Charon system at nearly 40,000 mph (63,000 km/h). The spacecraft makes its closest approach to both bodies less than 15 minutes apart.

ASTRONOMY: KELLIE JAEGER

Of equal importance, few in the 1930s could have imagined how much Pluto would tell us about a vast new part of the solar system, one lying beyond Neptune. Until the 1990s, tiny, misfit Pluto was so out of sync with the rest of the planets that theories for its origin grasped at straws, suggesting it might be an escaped asteroid, a lost moon of Neptune, or even a giant comet. But with the discovery of more than 1,000 Kuiper Belt objects (KBOs) orbiting the Sun beyond Neptune, Pluto's context at last became clear.

The ninth planet is the biggest and brightest object of what I like to call the solar system's third zone, the Kuiper Belt. The first zone contains the rocky planets — Mercury through Mars — while the second zone contains the great gas giants, Jupiter through Neptune. Pluto and the Kuiper Belt thus represent a clear break from the other types of objects the solar system formed. If all goes well, planetary scientists will get their first close-up look at "third zone" objects in 2015, when New Horizons rushes past Pluto and Charon.

Into the Kuiper Belt

Astronomers Kenneth Edgeworth and Gerard Kuiper predicted the Kuiper Belt's existence some 50 years ago. They and other astronomers of the time postulated that a belt of debris left over from planetary formation might orbit the Sun beyond Neptune.

S. Alan Stern *is the principal investigator for the New Horizons mission and a frequent contributor to* Astronomy *magazine.*

Unfortunately, the telescopic and photographic technology of the mid-20th century was too primitive to give astronomers much hope of finding small bodies at these great distances, so the Kuiper Belt remained only a hypothesis for decades.

By the late 1980s, astronomers studying comets noticed a pattern in the way the orbits of comets controlled by Jupiter's gravity were inclined. From this pattern, they found strong evidence that a disk-shape reservoir of comets lies just beyond Neptune's orbit. With powerful tools like CCD cameras and computers for data analysis, astronomers began searching for the belt of material Kuiper had predicted. In 1992, they found the first object orbiting there in addition to Pluto-Charon. This body, designated 1992QB$_1$, is more than 1,000 times fainter than Pluto, and perhaps only about 1/10 to 1/15 Pluto's size. As a result of this discovery, astronomers began referring to this outer region as the Kuiper Belt, and to bodies like 1992QB$_1$ as Kuiper Belt objects.

THIS FIRST EXPLORATION OF Pluto, Charon, and the Kuiper Belt promises to be a scientific watershed.

We've cataloged more than 1,000 KBOs ranging in diameter from roughly 20 to 930 miles (30 to 1,500 kilometers). We expect the KBO size distribution includes still smaller comet-size objects as well as larger objects close to Pluto's size (1,475 miles, or 2,360 km).

We can estimate the total population in the Kuiper Belt based on the amount of sky left to be searched and the number of distant, faint, moving objects being found in deep CCD images of the Kuiper Belt. In all, more than 100,000 KBOs larger than Eros, one of the largest near-Earth asteroids (25 miles, or 40 km), may orbit the Sun in the Kuiper Belt, the region between about 30 to 55 astronomical units (AU). (1 AU is the average Earth-Sun distance.)

Such a large estimated population means the Kuiper Belt contains a far greater collection of large objects than the asteroid belt, between Mars and Jupiter. For comparison, only a few thousand asteroids exist in this size range.

Based on the sizes and orbits of known KBOs, planetary scientists think the Kuiper Belt was well on its way to growing one or more large planets, perhaps even something the size of Earth, when the planetary growth process there was interrupted. Either a passing star from the Sun's birth cluster or the nearby formation of Neptune probably disturbed the region gravitationally, cutting off the accretion of large bodies.

Astronomers think this same disturbance changed the way objects collided in the young Kuiper Belt. What had been gentle bumps that promoted mergers

/// NEW HORIZONS' SCIENCE SUITE

The primary remote-sensing devices on New Horizons are **Ralph** and **Alice**, named for the main characters in the 1950s television show *The Honeymooners*. Ralph is a mapping camera combined with an infrared spectrometer and is designed to pick up surface compositions and temperatures. Alice is an ultraviolet spectrometer that will study the structure and composition of Pluto's upper atmosphere.

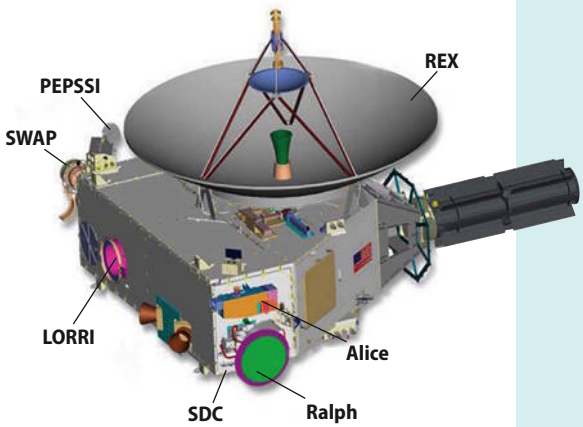
Another camera, called **LORRI** — for Long Range Reconnaissance Imager — is less versatile than Ralph but offers higher resolution. LORRI lets New Horizons study Pluto from much greater distances than Ralph and will provide the most detailed images during the flyby. Ralph, Alice, and LORRI can do their jobs even though the sunlight on Pluto is about 1,000 times weaker than on Earth.

New Horizons also carries two plasma sensors, called **PEPSSI** and **SWAP**, which will study electrically charged gases escaping Pluto's atmosphere.

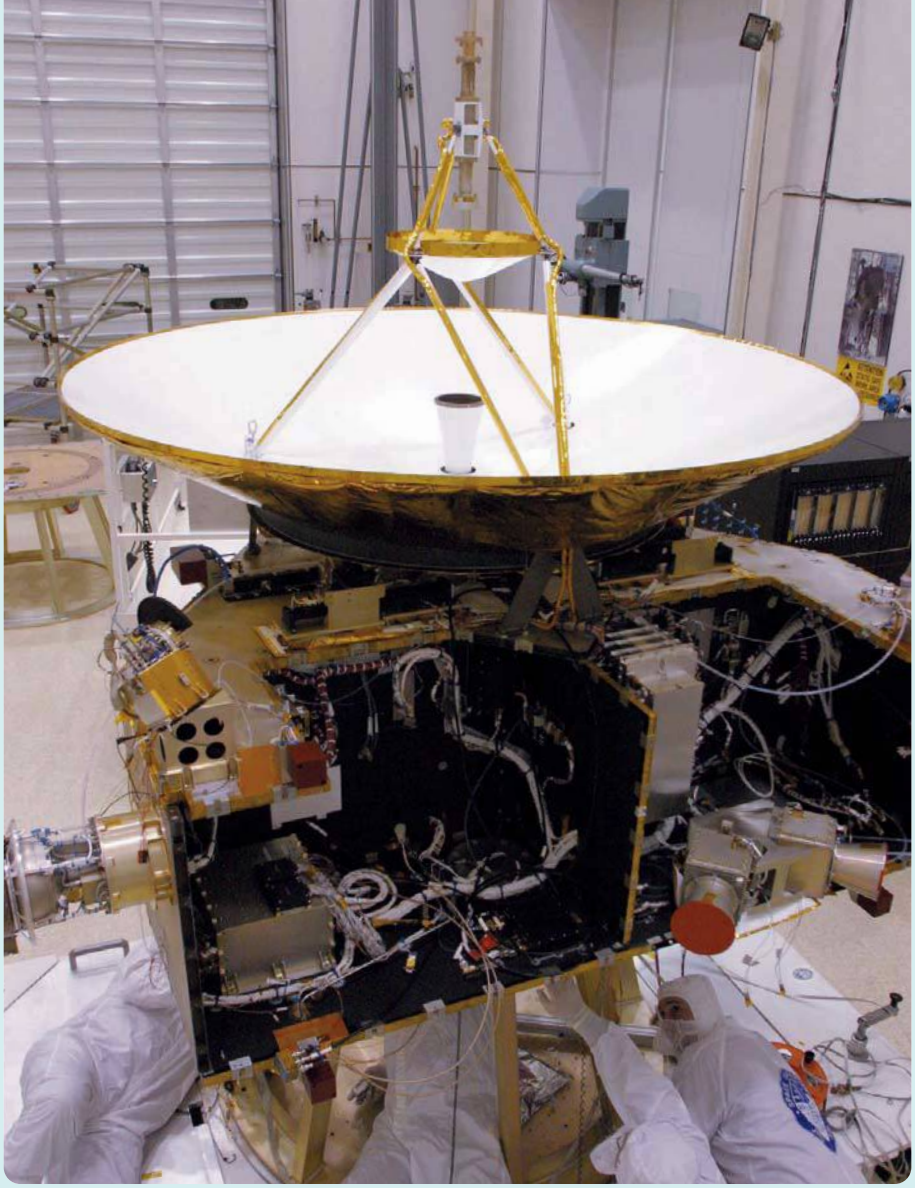
A radio science experiment (**REX**) will probe Pluto's lower atmosphere and measure the individual masses of Pluto, Charon, and any KBOs encountered.

New Horizons also carries the first planetary science instrument built by students. The Student Dust Counter (**SDC**) will measure the density of dust particles across the outer solar system and into the Kuiper Belt — something never before accomplished.

— S. A. S.



NEW HORIZONS' seven instruments range from cameras to a dust counter. NASA/SWRI



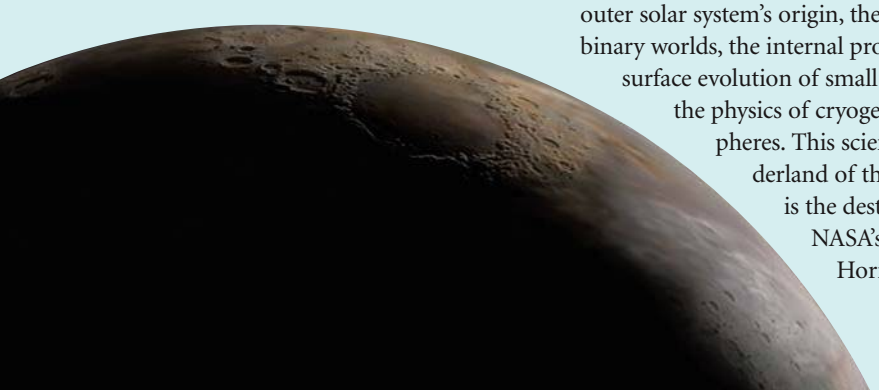
NASA/JHUAPL/SWRI

TEAM MEMBERS TAKE A LOOK under New Horizons' hood during a February 2005 "fit check" of the main antenna at Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland. The dish, which is nearly 7 feet (2.1 meters) wide, will beam to Earth gigabytes of images and other data gathered by the probe.

became violent, body-shattering impacts. These powerful collisions pulverized the objects taking part in them, eroding much of the Kuiper Belt's mass into dust, which was blown into interstellar space by the pressure of sunlight — depleting the feedstock of future growth. Similar processes have been seen in disks surrounding many stars in the galaxy, such as nearby Vega and Fomalhaut.

Priority one

The discovery of the Kuiper Belt fueled a revolution in our understanding of the origin, architecture, and richness of the deep outer solar system. Together, Pluto-Charon and the Kuiper Belt constitute an exciting frontier for planetary science. As noted earlier, the National Academy of Sciences called Pluto-Charon and the Kuiper Belt rich with possibilities for illuminating the outer solar system's origin, the nature of binary worlds, the internal properties and surface evolution of small bodies, and the physics of cryogenic atmospheres. This scientific wonderland of the Kuiper Belt is the destination of NASA's New Horizons.



Part of Pluto's allure is its mysterious atmosphere and the intimate coupling between this atmosphere and the planet's complex surface. Pluto's atmosphere is, at best, a few millionths of sea-level pressure on Earth. Yet, it generates snow, transports volatile material across the surface in seasonal flows, and may even have day-to-day variations we might think of as weather.

Earth's atmosphere contains only one gas (water vapor) that can undergo phase transitions to other states (solid and liquid). Pluto's atmosphere contains at least three such gases — nitrogen, carbon monoxide, and methane. Combine Pluto's weird atmosphere with the 120° tilt of its axis and its highly eccentric orbit around the Sun, and one has what must be the most complex seasonal weather pattern in the solar system.

Pluto's low gravity — just 6 percent of Earth's — lets its atmosphere escape at a furious pace. In fact, Pluto loses its atmosphere so fast, planetary scientists believe it's actually escaping hydrodynamically, which means most atmospheric molecules have enough kinetic energy to escape the planet directly once they reach high altitude.

We don't observe hydrodynamic escape on any other planet today, but astronomers believe this phenomenon was responsible for the early, rapid loss of hydrogen from Earth's atmosphere that helped make our world habitable. Pluto is the only planet in the solar system where we can study this important process acting today.

Pluto's density, size, and surface composition are strikingly similar to Neptune's large satellite Triton. One of the surprises of Voyager 2's 1989 exploration of the Neptune system was the discovery of vigorous internal activity on Triton. Will Pluto also show evidence of internal activity?

Charon, half of Pluto's size, presents still more puzzles. Pluto and Charon constitute the only "double planet" in our solar system. No space mission has yet visited any binary object, despite the increasing pace of double asteroid and double KBO discoveries.

And no one understands fully why Pluto and Charon look so different from each other. Pluto has an atmosphere, an unusually shiny surface with distinct

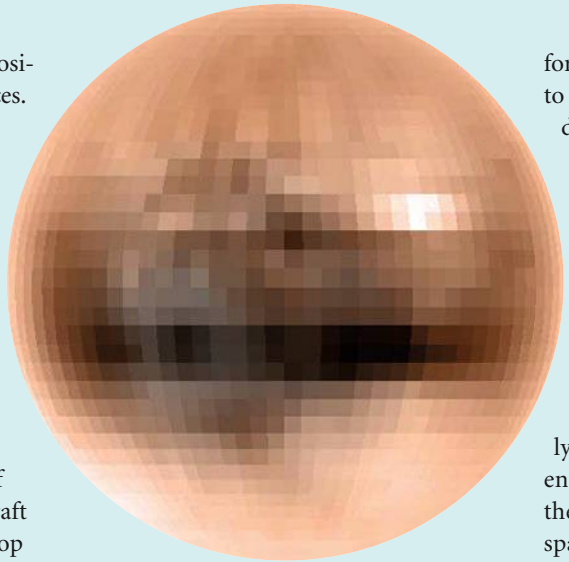
markings, and a complex surface composition that includes a variety of volatile ices.

Charon has no apparent atmosphere, and its surface reflects less light and shows only subtle, indistinct markings. Did their size and compositional differences allow Pluto and Charon to follow sharply divergent evolutionary paths? Or did they form with those differences in place? Right now, we know too little about Pluto and Charon to constrain the possibilities.

Just before the National Academy of Sciences panel recommended a spacecraft visit to Pluto and the Kuiper Belt as a top priority, university and industrial groups had competed to design a mission. In late 2001, NASA selected New Horizons, a joint effort led by the Southwest Research Institute (SWRI) in San Antonio, and the Johns Hopkins Applied Physics Laboratory (APL) in Laurel, Maryland.

The New Horizons spacecraft has a mass of about 1,060 pounds (481 kilograms), including its onboard maneuvering fuel. The spacecraft subsystems, almost all of which have redundancy, share a common heritage with other APL missions, such as NEAR-Shoemaker, which orbited asteroid 433 Eros in 2000, and the MESSENGER mission now en route to orbit Mercury. New Horizons was designed to operate as far as 50 AU from the Sun.

The mission's primary scientific goals are to map the surface features and compositions of Pluto and Charon, and to determine the composition of Pluto's atmosphere. Secondary goals include stereo surface mapping of Pluto, temperature mapping across the faces of Pluto and Charon, searching for additional satellites, and studying Pluto's electrically charged upper atmosphere.



OUR BEST VIEW OF PLUTO thus far comes from computer-generated maps derived from Hubble Space Telescope images. This view shows the side of Pluto always facing its moon, Charon. SWRI

Amazingly, the entire New Horizons science payload — seven instruments — weighs less than just the mapping camera on NASA's Saturn-orbiting Cassini mission, and it draws less power than a 30-watt lightbulb.

To Pluto and beyond

New Horizons is planned to launch aboard an Atlas V booster. The spacecraft will use a gravity-assist from Jupiter in 2007 to increase speed and reduce New Horizons' travel time to Pluto by several years. New Horizons will observe Jupiter for more than 6 months. Closest approach to Jupiter will occur in March 2007 at a distance of about 30 times Jupiter's radius — more than 4 times closer than Cassini passed during its 2000 flyby.

After its Jupiter encounter, New Horizons will cruise for almost 8 years to reach Pluto. It will hibernate most of the time, waking up only for course corrections, annual checks of its systems and instruments, and rehearsals for the intricately choreographed Pluto-Charon encounter sequence. As it moves through the outer solar system, the New Horizons spacecraft will also provide periodic reports on the solar wind and count dust-particle impacts.

The Pluto-Charon encounter itself begins 6 months prior to closest approach. For 75 days on either side of closest approach, New Horizons will make images of Pluto-Charon better than those obtained from the Hubble Space Telescope — our best views to date. During the long approach phase, the craft's instruments will study time-variable phenomena, such as Pluto's weather.

Near closest approach, which may be as close as a few thousand miles from Pluto, New Horizons will obtain detailed maps of both Pluto and Charon with 0.6-mile (1 km) resolution. When closest to Pluto, the craft's cameras may achieve resolution as high as 30 yards (25 meters) per pixel. As the spacecraft's path takes it through zones where Pluto passes in front of the Sun and Earth, ultraviolet sunlight and radio signals will probe Pluto's atmosphere.

As New Horizons leaves the Pluto-Charon system, it will radio to Earth its gigabytes of data and then, if it is healthy enough, fire its engines to target its first KBO. Studies indicate the craft may be able to reach one, or possibly two, KBOs in the years following the Pluto encounter.

This first exploration of Pluto, Charon, and the Kuiper Belt promises to be a scientific watershed. It will complete our reconnaissance of the solar system and open up the exploration of the Kuiper Belt. Perhaps most inspiring, it will provide a new and vivid demonstration of the historic kind of space exploration only the United States can achieve. A

/// NEW HORIZONS: THE SEQUEL?

While New Horizons will revolutionize our knowledge of the outer solar system, it is a single spacecraft sent on a mission to a far-away place. What if something goes wrong?

In the past, NASA often sent twin probes to increase the chance of a successful mission. Viking 1 and 2 (1976) to Mars, Voyager 1 and 2 (1977) to the outer planets, and the spectacularly successful twin Mars rovers, Spirit and Opportunity (2003), each gave one-two punches for science and exploration.

Recognizing the perils of conducting the New Horizons mission with a single probe, as well as the potential for expanded exploration of the Kuiper Belt, the United States Congress has requested a study of a second New Horizons mission.

A twin New Horizons spacecraft could be launched in 2008 or 2009. One proposed trajectory would swing the craft past Uranus, which was visited only once by Voyager 2, on its way to the Kuiper Belt.

Because the design work is already complete and many spares exist, building a second spacecraft would cost much less than the original. — *S. A. S.*

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A GHOSTLY CORONA and fiery red prominences leap from the Sun's limb during totality, creating a striking vision no viewer will soon forget. FRED ESPENAK

SOLAR ECLIPSE

Totality reigns over Africa and Asia

The longest total solar eclipse in nearly 5 years cuts a path across northern Africa and western Asia March 29. At the eclipse's maximum, as seen from the border between Chad and Libya, the Sun will disappear for 4 minutes and 7 seconds. The long duration and excellent weather prospects make this a must-see event.

oct 2005

A ring of SUNLIGHT

Two solar eclipses vie for attention in 2005. On April 8, the Moon blocked the Sun totally from view for up to 42 seconds. The catch: You had to be in the South Pacific to see it. Then, October 3, people in parts of Europe and Africa will see a ring of sunlight for more than 4 minutes. Observers will have to wait only until March 2006 for their next long view of totality.

RON LEE

A GOLDEN RING OF LIGHT greets observers during an annular eclipse, when the Moon is not quite big enough to block all of the Sun.

The Iberian Peninsula will be the center of the astronomical universe this October as the Moon's shadow sweeps across the region. On October 3, the Moon will pass directly in front of the Sun. Because the Moon lies relatively far from Earth that day, it doesn't appear big enough to block the Sun totally from view. A ring of sunlight will remain at maximum eclipse. Such eclipses are called annular, from the Latin word *anulus*, meaning "ring." Ninety-six percent of the Sun will be covered during this annular eclipse, bringing a gloom to areas along the path.

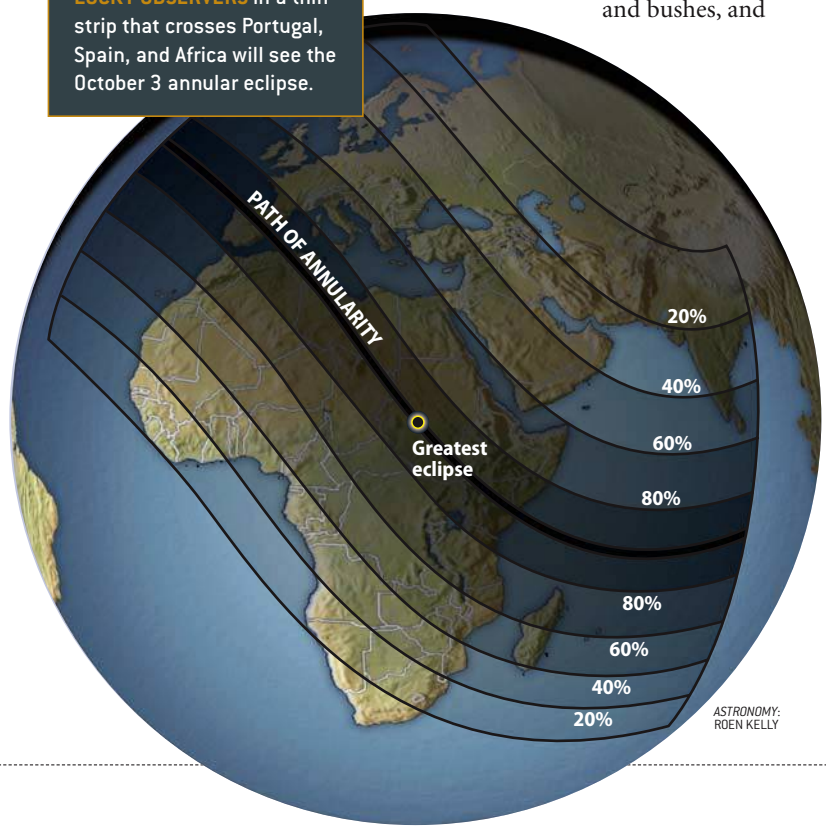
After sweeping across northern Portugal and central Spain, the path traverses the Mediterranean Sea and heads into Africa. There, it makes a beeline across the continent from northeastern Algeria to southern Somalia. Every land-based location along the center line experiences at least 4 minutes of annularity. Madrid, which lies just off the center line, gets 4 minutes and 11 seconds. Observers across most of Europe and Africa and much of southern Asia will witness a partial solar eclipse.

Even though 96 percent of the Sun is hidden from view, the remaining 4 percent can do great harm to anyone who looks directly at it without proper eye protection. Either project an image of the Sun onto a piece of white cardboard or use a piece of aluminized mylar, a #14 welder's glass, or a high-quality solar filter that blocks almost all of the Sun's visible, ultraviolet, and infrared radiation.

Unfortunately, the Sun's glorious corona and ruddy prominences remain hidden during an annular eclipse. Still, there's plenty to watch. Although someone following the Moon's march across the Sun's face will notice the eclipse's progress, to others, the signs are subtle until about half the Sun is blocked. As the source of light in the sky grows smaller, you'll start to notice that shadows appear sharper.

Once the Moon covers about 80 percent of the Sun, shift your attention from the sky to the ground. Look closely at sunlight filtering through the leaves of trees and bushes, and

LUCKY OBSERVERS in a thin strip that crosses Portugal, Spain, and Africa will see the October 3 annular eclipse.



ASTRONOMY: ROEN KELLY

OCTOBER 05

S	M	T	W	T	F	S
						1
2	○	4	5	6	7	8
9	◑	11	12	13	14	15
16	●	18	19	20	21	22
23	◐	25	26	27	28	29
30	31					

3	Annular solar eclipse, 6 A.M. EDT	👁 🔭
4	Mercury passes 2° north of Spica, 4 A.M. EDT	👁
6	Mercury passes 1.5° south of Jupiter, 3 A.M. EDT	👁
7	The Moon passes 1.4° south of Venus, 2 A.M. EDT	👁
	The Moon passes 0.2° north of Antares, 9 P.M. EDT	👁 🔭
12	The Moon passes 5° south of Neptune, 11 A.M. EDT	
14	The Moon passes 3° south of Uranus, 1 A.M. EDT	
16	Venus passes 1.6° north of Antares, 2 P.M. EDT	👁
17	Partial lunar eclipse, 8 A.M. EDT	👁 🔭
19	The Moon passes 5° north of Mars, 9 A.M. EDT	👁
21	Orionid meteor shower peaks	👁
22	Jupiter is in conjunction with the Sun, 9 A.M. EDT	
25	The Moon passes 4° north of Saturn, 1 P.M. EDT	👁
31	The Moon passes 1.2° north of Spica, 2 P.M. EST	👁

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

SHERRI MARTIN

THE MOON'S SOUTHERN LIMB will grow dark during a partial lunar eclipse October 17, mimicking this view from the October 1987 penumbral eclipse.

you'll see hundreds or even thousands of tiny images of the crescent Sun. The openings between the leaves serve as pinholes that project images of the eclipsed Sun.

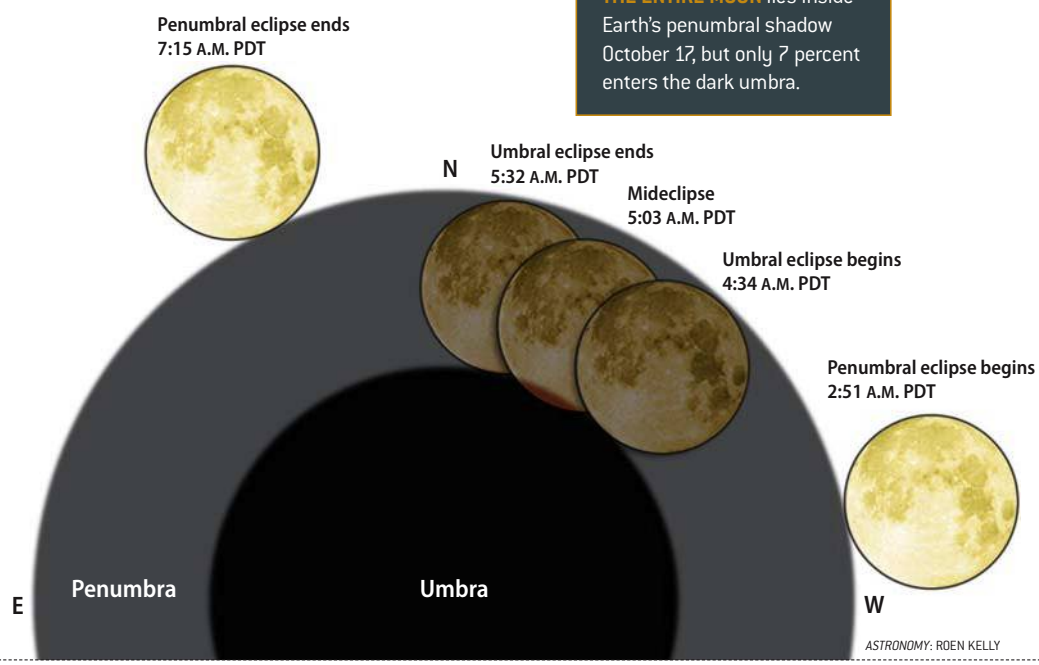
Into a partial shadow

Two weeks after the Moon blocks the Sun from view, Earth returns the favor. On the morning of October 17, people in most of North America have the chance to see the Moon pass into Earth's shadow. (For those in Australia, New Zealand, and eastern Asia, the eclipse takes place on the evening of the 17th.) Although only 7 percent of the Moon falls within Earth's dark umbral shadow at maximum, the Moon's entire disk lies within the lighter penumbral shadow. Observers can expect to see a bite taken out of the Full Moon's southern limb, while the rest of the disk takes on a more grayish hue than normal. Don't expect the ruddy color seen during a total lunar eclipse.

The penumbral phase of the eclipse gets underway at 5:51 A.M. EDT (subtract 1 hour for CDT, 2 hours for MDT, and 3 hours for PDT). The Moon hits the umbral shadow at 7:34 A.M. EDT. By then, the Moon has set along the East Coast but remains above the western horizon elsewhere across the continent.

Maximum eclipse arrives at 8:03 A.M. EDT, and the umbral phase concludes at 8:32 A.M. EDT. By this time, the Moon has set everywhere east of a line that runs from eastern Texas north to the arrowhead of Minnesota. The penumbral phase ends at 7:15 A.M. PDT and can be seen only from the West Coast.

THE ENTIRE MOON lies inside Earth's penumbral shadow October 17, but only 7 percent enters the dark umbra.



ASTRONOMY: ROEN KELLY

2005 nov

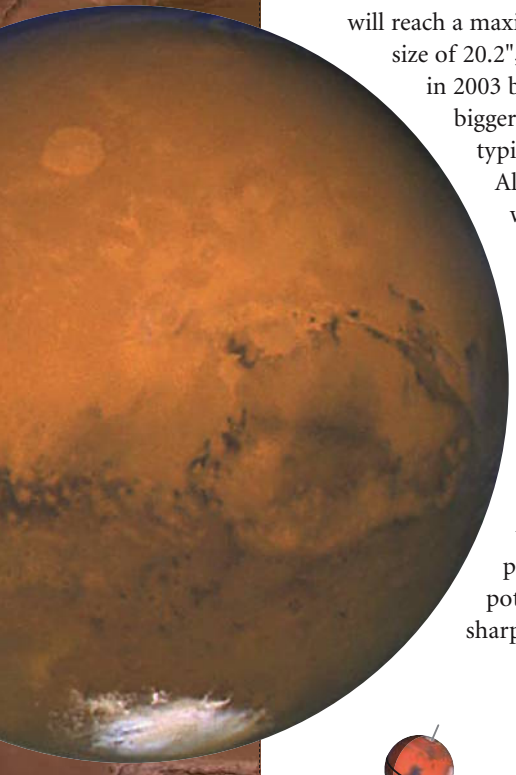
MARS returns to GLORY

Memories remain fresh of the appearance of Mars during the summer of 2003. The Red Planet came closer to Earth than at any time in 60,000 years, and it won't be as close again for more than 20,000 years. But Mars viewers shouldn't toss out their scopes yet — autumn 2005 brings Mars close again, and it will offer great views to anyone who makes the effort.

NASA/STScI

MARS MANIA will sweep Earth again in late 2005, as the Red Planet puts on a show just slightly less grand than it did in 2003.

Mars follows its record-breaking 2003 opposition with an excellent return in autumn 2005. The planet will reach a maximum apparent size of 20.2", 5" smaller than in 2003 but significantly bigger than it is at a typical opposition. Although Mars won't be as close as it was 2 years ago, it will be at a much higher elevation — 30° higher for Northern Hemisphere observers — yielding long periods with potentially much sharper views.



You actually could see Mars throughout 2005. At the start of the year, it appeared in the predawn sky among the stars of Scorpius. Then, it slowly made its way across Ophiuchus, Sagittarius, and Capricornus, where it passed 1.2° south of Neptune April 12/13. A month later, May 14, Mars stood the same distance south of Uranus. The two planets lay in the eastern section of Aquarius. Mars appeared bright, shining at magnitude 0.5, but with a diameter of just 7", it didn't show much detail through a telescope.

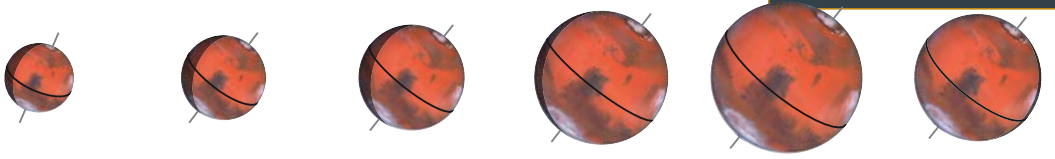
Attention grew when Mars crossed the 10"-diameter threshold July 13. From then through the end of the year, Mars presents a fine telescopic target. July found Mars rising around midnight and standing 45° above the southeastern horizon as twilight started to paint the sky. This altitude already beat the best of the 2003 apparition by 10°. By the end of July, Mars had brightened considerably, gleaming at magnitude –0.5, and it dominated the morning sky.

Mars begins its retrograde (westward) motion in early October, when it lies on the border between Taurus and Aries. After spending 2 weeks in Taurus, the planet's path carries it back into Aries. Mars remains among the stars of the Ram for the rest of the year.

Don't miss these early opportunities for viewing Mars. By the time opposition rolls around November 7, the best viewing period already will be half over. Although there were no global dust storms in 2003, there's no guarantee we'll be so lucky this time. Mars is notorious for throwing surprises. The Red Planet reached perihelion, its closest approach to the Sun, in mid-July, and dust storms frequently appear around this time.

The Red Planet appears at its finest in late October and early

THE VIEW OF MARS through a telescope will be grand in late 2005, as the planet's diameter swells to 20" and its south pole tilts in our direction.



July 1, 2005
Disk size = 9.3"
Magnitude = –0.1

August 1, 2005
Disk size = 11.3"
Magnitude = –0.5

September 1, 2005
Disk size = 14.1"
Magnitude = –1.0

October 1, 2005
Disk size = 17.8"
Magnitude = –1.7

November 1, 2005
Disk size = 20.2"
Magnitude = –2.3

December 1, 2005
Disk size = 16.9"
Magnitude = –1.6

ASTRONOMY: ROEN KELLY

NOVEMBER 05

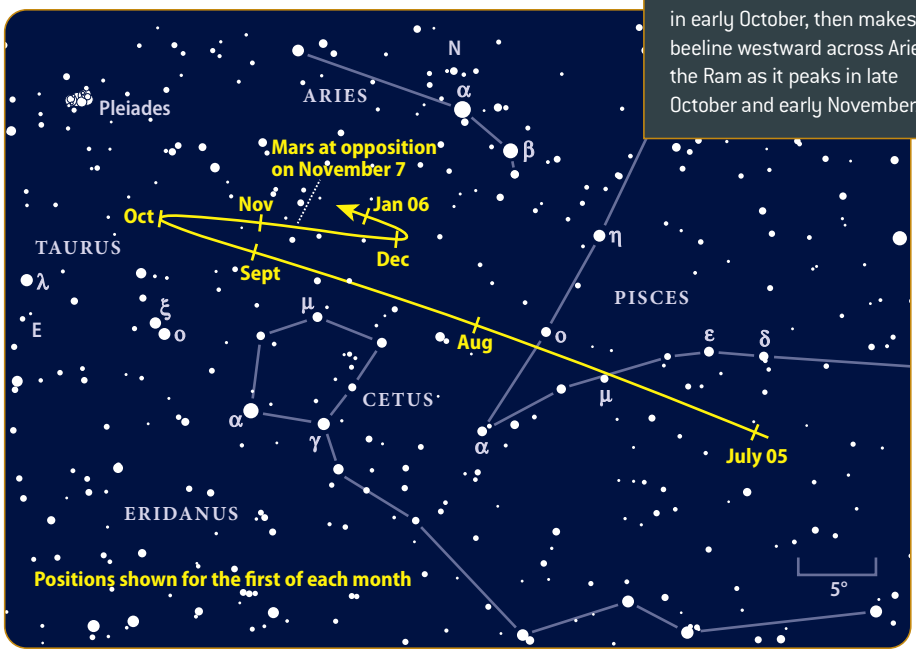
S	M	T	W	T	F	S
		○	2	3	4	5
6	7	◑	9	10	11	12
13	14	●	16	17	18	19
20	21	22	◐	24	25	26
27	28	29	30			

3	Mercury is at greatest eastern elongation (24°), 11 A.M. EST	
	Venus is at greatest eastern elongation (47°), 2 P.M. EST	
4	The Moon passes 0.2° north of Antares, 2 A.M. EST	
5	The Moon passes 1.4° south of Venus, 2 P.M. EST	
7	Mars is at opposition, 3 A.M. EST	
8	The Moon passes 5° south of Neptune, 3 P.M. EST	
10	The Moon passes 3° south of Uranus, 5 A.M. EST	
15	The Moon passes 3° north of Mars, 1 A.M. EST	
17	Leonid meteor shower peaks	
21	The Moon passes 4° north of Saturn, 10 P.M. EST	
24	Mercury is in inferior conjunction, 11 A.M. EST	
27	The Moon passes 1.1° north of Spica, 11 P.M. EST	
29	The Moon passes 3° south of Jupiter, 3 A.M. EST	

LEGEND

	Events that can be viewed with the naked eye
	Events that can be viewed with binoculars
	Events that can be viewed with a telescope

MARS REVERSES DIRECTION in early October, then makes a beeline westward across Aries the Ram as it peaks in late October and early November.



ASTRONOMY: ROEN KELLY

November. For a period of 2 weeks, from October 23 to November 6, the planet spans at least 20.0". Mars actually comes closest to Earth — and thus appears its largest — a week before its November 7 opposition. On October 30, it lies 43.1 million miles away and has a diameter of 20.2". Mars shines brightest at opposition, however, reaching magnitude –2.3. It then rises at sunset and appears highest in the south around midnight. The planet lies 65° above the horizon, as seen from a latitude of 40° north, and dominates the southern sky.

The most famous feature on the Red Planet is Syrtis Major. Its distinctive dark, triangular shape will be well-placed for observation during the peak viewing period. On October 24, it lies on the central meridian of Mars at 9 P.M. EDT. One week later, Syrtis Major reaches the disk's center around midnight EST.

By opposition November 7, the dark Solis Lacus region will be rotating out of view in the early evening, while Syrtis Major is centrally located in the early morning hours.

After opposition, Mars fades quickly, dimming to magnitude –1.0 by December 19. By the second half of December, Mars resumes its easterly trek relative to the stars. In February, the planet will pass 2° south of the Pleiades star cluster, providing a nice contrast between its ruddy hue and the cluster of blue-white stars.

MARS EXPRESS will continue to send back images like this one, which shows lava channels on the southern flank of the volcano Ascraeus Mons.

ESA

dec 2005

The brilliant EVENING STAR

Few sights impress casual stargazers more than seeing the brilliant planet Venus gleaming in a twilit sky. This year provides several opportunities to Venus-gaze. The planet took on the role of "morning star" in the first weeks of 2005, then it returned as the "evening star" during the second half of the year. Venus appears most prominent during November and December.

JOHN McNEAL

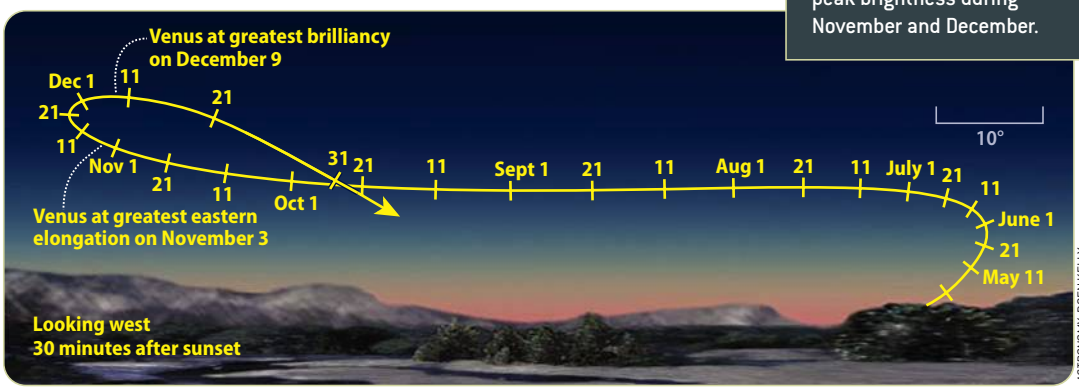
VENUS GLEAMS BRILLIANTLY in the evening sky at the end of 2005, but it appears truly striking when paired with a crescent Moon, as it will be December 4.

Venus appeared low in the southeast before dawn for the first weeks of January, passing just 1.2° below Mercury on New Year's morning. Venus then became lost in the solar glare by the end of the month and did not return to view until May, when it lay in the evening sky. On May 20, it set 1 hour after the Sun and appeared among the background stars of Taurus the Bull. At the same time, Saturn lay about 35° above the western horizon. Over the next several weeks, Venus played catchup with Saturn. A dramatic conjunction among these two and Mercury occurred in late June.

During June, Venus raced across the constellation Gemini the Twins. A slender crescent Moon passed 6° above Venus on the 8th. One evening later, the Moon lay 5° north of Saturn. By the middle of the month, Mercury came into view below Venus and Saturn and, each day, climbed closer to the planetary duo. The three planets were closest together June 25, when they lay within 1.5° of one another. If you watched each evening leading up to and following this date, the planets changed relative positions in a wonderful celestial dance.

On June 25, Venus and Mercury lay 0.5° apart, with Saturn 1.3° south of Venus. Venus appeared far brighter than the other two, and Mercury was a shade brighter than Saturn. The next night, Venus stood 1.7° above Saturn. Venus and Mercury lay 0.2° apart and could be seen in the same telescopic field of view. Mercury showed a slightly gibbous disk, while Venus appeared 92-percent lit. By June 27, Mercury had moved from west of Venus to southeast but still lay within 0.2°. Both Venus and Mercury had started to pull away from Saturn, which now lay 2.5° below Venus.

VENUS APPEARS low in the evening sky throughout the latter half of 2005, climbing to its maximum altitude and peak brightness during November and December.



ASTRONOMY: ROEN KELLY

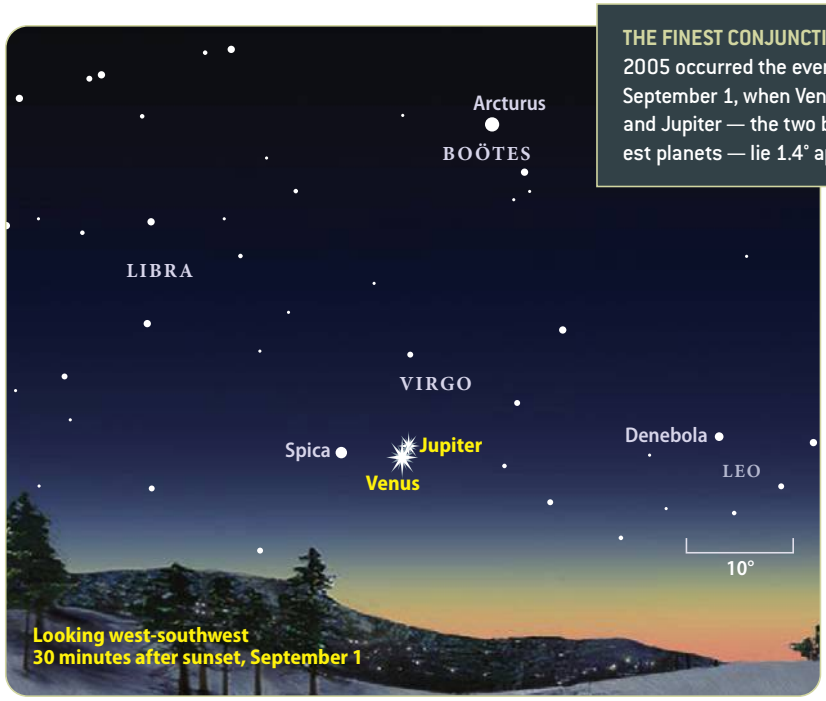
DECEMBER 05

S	M	T	W	T	F	S
				○	2	3
4	5	6	7	◑	9	10
11	12	13	14	●	16	17
18	19	20	21	22	◐	24
25	26	27	28	29	○	31

4	The Moon passes 2° south of Venus, 1 P.M. EST	👁 🔭
5	The Moon passes 4° south of Neptune, 10 P.M. EST	🔭
7	The Moon passes 2° south of Uranus, 11 A.M. EST	🔭
9	Asteroid Juno is at opposition, 3 A.M. EST	🔭 🔭
	Venus is at greatest brilliancy, (magnitude –4.6), 8 A.M. EST	👁 🔭 🔭
11	The Moon passes 1.3° north of Mars, midnight EST	👁 🔭
12	Mercury is at greatest western elongation (21°), 8 A.M. EST	👁 🔭 🔭
13	Geminid meteor shower peaks	👁
15	Pluto is in conjunction with the Sun, 11 P.M. EST	
19	The Moon passes 4° north of Saturn, 4 A.M. EST	👁 🔭
21	Solstice (northern winter/ southern summer begins), 2 P.M. EST	👁
25	The Moon passes 0.9° north of Spica, 9 A.M. EST	👁 🔭 🔭
26	The Moon passes 4° south of Jupiter, 11 P.M. EST	👁 🔭
28	The Moon passes 0.2° north of Antares, 9 P.M. EST	👁 🔭 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope



ASTRONOMY: ROEN KELLY

THE FINEST CONJUNCTION of 2005 occurred the evening of September 1, when Venus and Jupiter — the two brightest planets — lie 1.4° apart.

While Saturn quickly fell into the evening twilight, Mercury and Venus remained visible each night as they crossed into Cancer the Crab. On July 3, Mercury and Venus straddled the Beehive star cluster (M44), and 1.2° separated the planets. Mercury had started to fade, however, and it became more difficult to see. An hour after sunset, the pair lay 5° high in the west-northwest. If you had a clear horizon, you would have seen the Beehive with binoculars as the planets set. The transparency of the atmosphere plays a critical role in observing such conjunctions.

On July 8, a crescent Moon stood 3° above Venus, while less than 4 Moon-widths separated Venus and Mercury. Two weeks later, the 22nd, Venus lay 1.2° north of Regulus, the brightest star in Leo the Lion. By then, Mercury had sunk back into the Sun's glow.

Throughout August, Venus closes the gap with the second brightest planet, Jupiter. On September 1, Venus appears just 1.2° below Jupiter, forming the finest planetary conjunction of the year. The bright star Spica in Virgo then lies 5° to the left of Venus. Five nights later, a waxing crescent Moon joins Venus, Jupiter, and Spica in an elegant quartet in the west-southwest 30 to 60 minutes after sunset.

Venus continues to hug the horizon throughout this period because the ecliptic — the apparent path of the Sun across the sky, which the Moon and planets also follow closely — makes a shallow angle to the western horizon after sunset this time of year. On October 16, Venus passes 1.6° north of Antares in Scorpius. On November 3, the planet reaches greatest elongation, lying 47° east of the Sun. Still, Venus lies only 12° high in the southwest an hour after sunset. Two nights later, a crescent Moon meets Venus in Sagittarius the Archer. Venus appears as a brilliant diamond then, shining at magnitude –4.4 against the glow of the Milky Way. This provides a fine opportunity for some stunning astrophotography.

This evening apparition of Venus provides an excellent opportunity to watch the size and phase of the brightest planet change. When Venus first appeared in the evening sky in May and June, it showed a 10"-diameter disk that was more than 90-percent illuminated. By August 31, the phase has shrunk to three-quarters lit while the size has grown to 15". Venus appears half-lit and 25" across at greatest elongation.

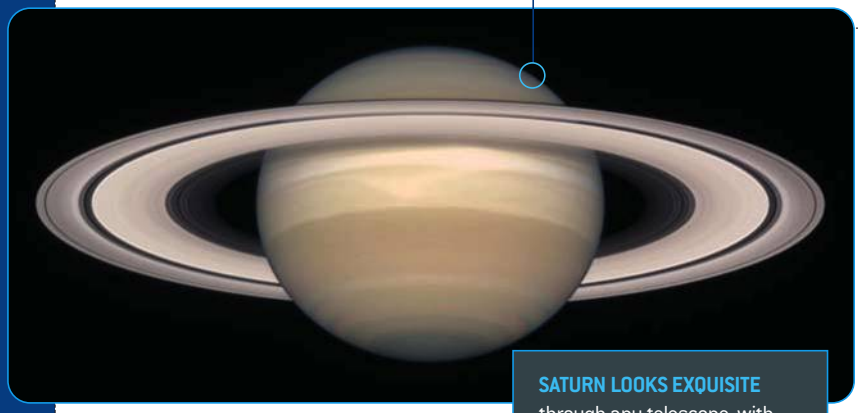
The final 2 months of the year see Venus change at an even greater pace. Its disk more than doubles in size between early November and late December, at which time it spans 58". Meanwhile, the phase shrinks to 33-percent lit November 30, 25-percent lit December 10, and 20-percent lit 5 days later. On New Year's Eve, Venus displays a 6-percent-illuminated disk and sets nearly 2 hours after the Sun.

2006 Jan

Saturn commands the winter sky

DISTANCE FROM THE SUN: 9.58 AU
ORBITAL PERIOD: 29.46 years
DIAMETER: 9.45 Earths
MASS: 95.16 Earths
DENSITY: 0.69 g/cc

Saturn kicks off 2006 in fine style, appearing at its biggest and brightest of the year during January. Don't pass up any opportunity to view the planet and its glorious rings through a telescope. Although Mars can't compete with Saturn in a beauty contest, the Red Planet certainly is worth a look this month also.



NASA AND THE HUBBLE HERITAGE TEAM (AURA/STScI)

SATURN LOOKS EXQUISITE through any telescope, with the rings in particular being a source of endless fascination.

Saturn's visibility in the night sky peaks in January, following months of excellent views before dawn. The ringed planet reaches opposition January 27, when it lies opposite the Sun in our sky and thus remains visible all night. It also shines brightest at opposition, gleaming at magnitude –0.2. That makes it brighter than any star in the sky except for Sirius and, for those in the Southern Hemisphere, Canopus. Any scope easily shows the ringed planet's 20"-diameter disk and the magnificent rings, which span more than twice what the disk does.

Saturn rises near sunset and appears high in the south around local midnight throughout most of January and February. The ringed planet spends the last week of January attractively placed less than 1° from the Beehive star cluster (M44) in the constellation Cancer the Crab. Binoculars will resolve the misty patch into 15 stars spread across a 1° field. A low-power view through a small telescope will show the brilliant disk and rings of Saturn next to a few dozen glittering stars in the Beehive.

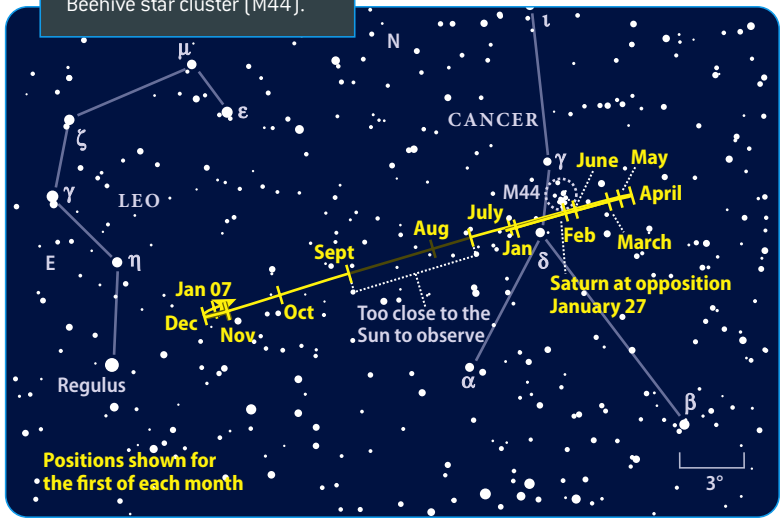
After opposition, Saturn continues to move westward until early April, by which time it has dimmed slightly to magnitude 0.1. In April, Saturn lies high in the south at sunset and sets after 2 A.M. local time.

During May, Saturn heads back toward the Beehive. Meanwhile, Mars enters Cancer May 30 along with a crescent Moon, which lies 3° north of the Red Planet. The following night, the crescent Moon stands 2° northeast of the Beehive. Saturn then lies 1 Moon-width southwest of the cluster, making an attractive grouping for naked-eye and binocular observers. Saturn passes due south of the Beehive again during the first week of June.

By mid-June, Saturn sets 3 hours after the Sun. On the 15th, Mars sits in front of the Beehive and Saturn lies slightly more than 1° to the southeast. Mars and Saturn come closest to each other June 17, when Mars lies 0.6° (about 1 Moon-width) north of the ringed planet.

Saturn descends into the twilight glow and disappears from view in late July, but Mars will remain

DON'T MISS SATURN in late January and early February, as it slides just south of the Beehive star cluster (M44).



ASTRONOMY: ROEN KELLY

JANUARY 06

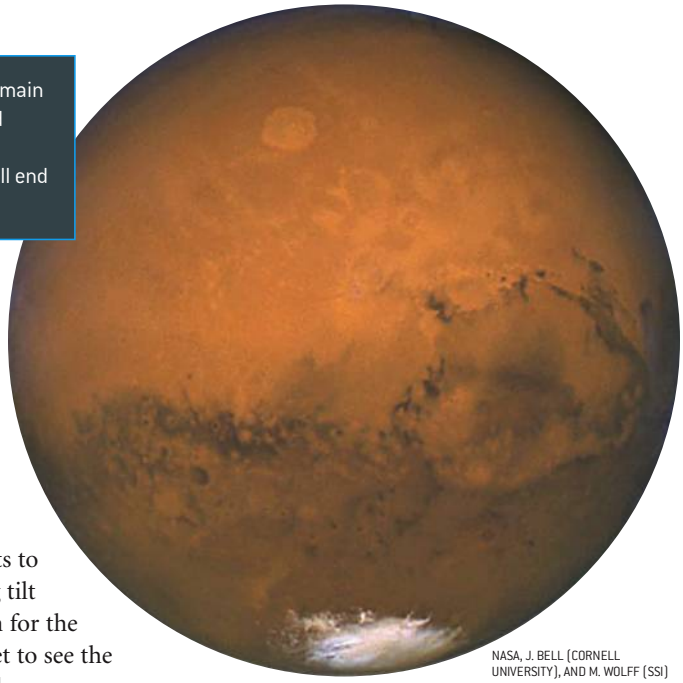
S	M	T	W	T	F	S
1	2	3	4	5	◑	7
8	9	10	11	12	13	●
15	16	17	18	19	20	21
◐	23	24	25	26	27	28
○	30	31				

1	The Moon passes 7° south of Venus, 5 A.M. EST	👁 🔭
2	The Moon passes 4° south of Neptune, 7 A.M. EST	🔭
3	Quadrantid meteor shower peaks	👁
	The Moon passes 2° south of Uranus, 7 P.M. EST	🔭
5	Asteroid Vesta is at opposition, 6 P.M. EST	🔭 🔭
8	The Moon passes 1.3° north of Mars, 3 P.M. EST	👁 🔭
13	Venus is in inferior conjunction, 7 P.M. EST	
15	The Moon passes 4° north of Saturn, 8 A.M. EST	👁 🔭
21	The Moon passes 0.6° north of Spica, 5 P.M. EST	👁 🔭 🔭
23	The Moon passes 5° south of Jupiter, 3 P.M. EST	👁 🔭
25	The Moon passes 0.02° north of Antares, 7 A.M. EST	👁 🔭 🔭
26	Mercury is in superior conjunction, 5 P.M. EST	
27	Saturn is at opposition, 6 P.M. EST	👁 🔭 🔭
	The Moon passes 12° south of Venus, 7 P.M. EST	👁
31	The Moon passes 1.7° south of Uranus, 7 A.M. EST	🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

DETAILS ON MARS will remain visible through backyard scopes in January, but prime-time observing will end after that.



NASA, J. BELL (CORNELL UNIVERSITY), AND M. WOLFF (SSI)

visible through August. Saturn reaches conjunction with the Sun August 7. By September, Saturn reappears in the morning sky and begins its trek toward another opposition in early 2007.

Our view of the rings starts to deteriorate this year. The ring tilt narrows with each opposition for the next few years, so we won't get to see the rings in all their glory. They'll appear edge-on to our line-of-sight in 2009.

The Cassini/Huygens spacecraft has changed our view of the saturnian system forever. Most exciting was last January's landing on Titan by the Huygens probe. Huygens transmitted images of Titan's surface, revealing detailed features on this once mysterious moon. Viewing 8th-magnitude Titan through a small telescope now takes on a new perspective.

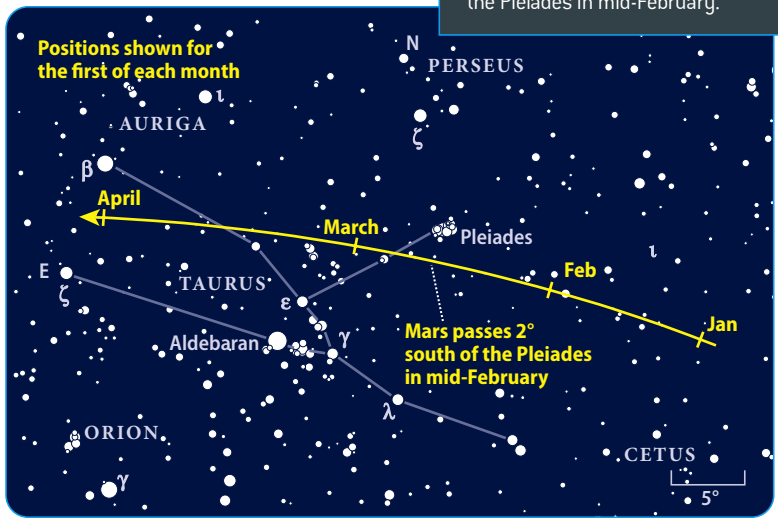
Last glimpse of Mars

The first month of the New Year presents the last chance for you to view much detail on Mars' surface. By February, the Red Planet will become too small to show such detail for all but the largest telescopes on nights with exceptional seeing.

The rest of us need to take advantage of January evenings for our Mars viewing. Mars still spans 12" January 1 and shrinks to 10" by the 18th. It shines at magnitude –0.6 to start the year but fades quickly, reaching magnitude 0.2 by month's end. It dominates the constellation Aries the Ram throughout this period. A waxing gibbous Moon passes Mars January 8.

The Moon returns to a location near Mars — and also the Pleiades star cluster (M45) — February 5. A few days later, the Red Planet crosses into Taurus the Bull. Mars stands 2° south of the Pleiades February 16. The apparent diameter of Mars continues to shrink about 1" every 2 weeks through March. It remains visible in the early evening sky through summer. Don't miss Mars' conjunction with Saturn near the Beehive star cluster in mid-June.

THE RED PLANET travels quickly through Aries and Taurus in the first 3 months of 2006, tracking south of the Pleiades in mid-February.

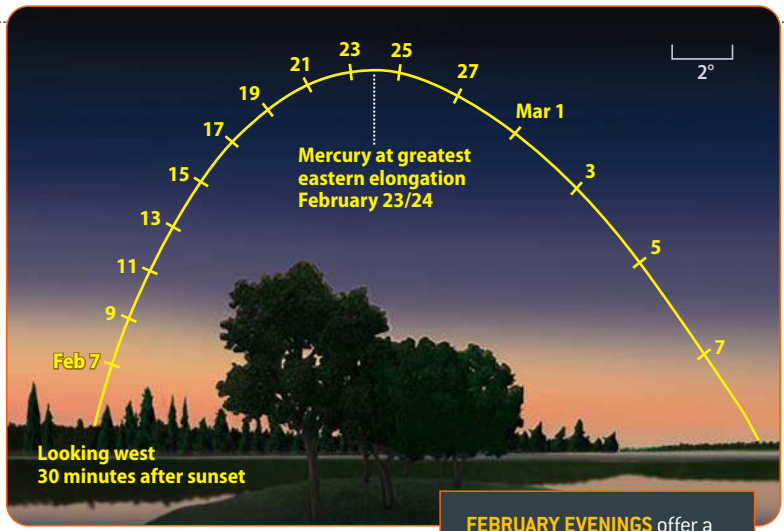


ASTRONOMY: ROEN KELLY

feb 2006

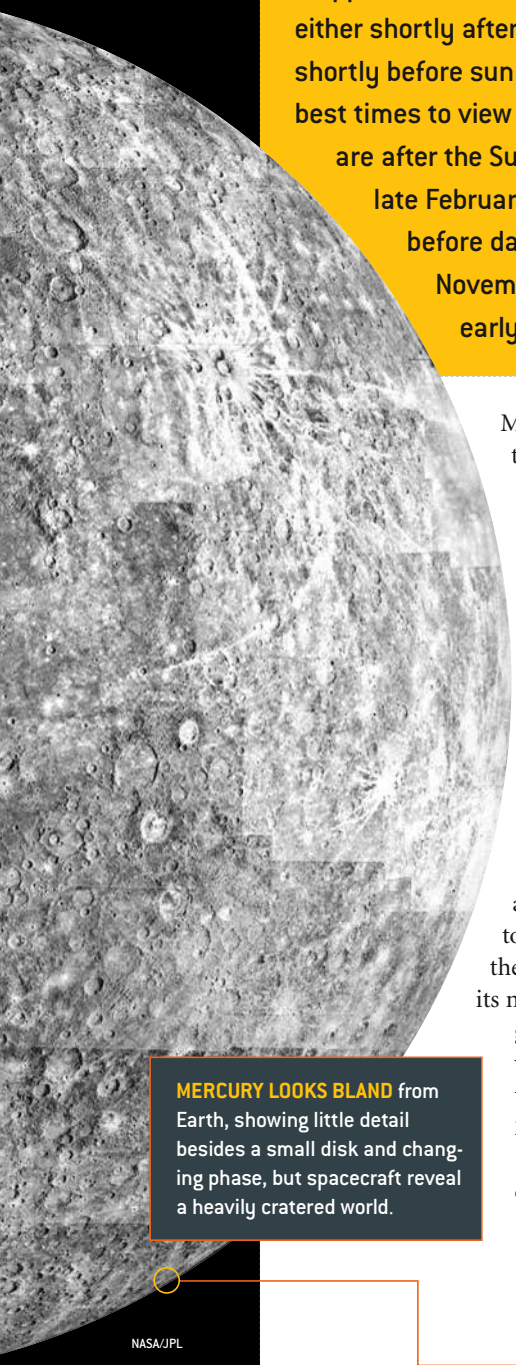
Tracking elusive Mercury

Mercury has a reputation for being hard to see. And it is — most of the time — because it appears near the horizon either shortly after sunset or shortly before sunrise. The best times to view it in 2006 are after the Sun sets in late February or just before dawn in late November and early December.



ASTRONOMY: TERRI FIELD

FEBRUARY EVENINGS offer a great chance to glimpse elusive Mercury, as it climbs in the western sky after sunset.



NASA/JPL

MERCURY LOOKS BLAND from Earth, showing little detail besides a small disk and changing phase, but spacecraft reveal a heavily cratered world.

Mercury orbits the Sun in a small ellipse that carries it around once every 88 days at an average distance of 36 million miles. Because Earth lies nearly 3 times farther from our star, Mercury always appears close to the Sun in the sky. Even at its maximum elongation, it never ventures more than 18° to 28° away.

Mercury climbs highest in the twilight sky, and thus appears most conspicuous, when its angular distance from the Sun translates into altitude above the horizon. This happens when the ecliptic — the apparent path of the Sun and planets across the sky — makes a steep angle with respect to the horizon. For Northern Hemisphere observers, this condition is met in the evening sky in late winter and early spring, and in the morning sky in autumn. If Mercury becomes visible at those times, it will be good viewing.

This year's best evening views come between February 8 and March 6. Still, Mercury pops above the western horizon for only a few weeks and just as quickly drops back into the solar glare. Even at its best, Mercury sets soon after the Sun. To catch the elusive planet, begin searching as soon as the western horizon starts to grow dark.

Mercury lies 10° from the Sun February 8 and sets about 45 minutes after sunset. It shines brightly at magnitude –1.4, so it will pop out of the twilight glow 25 minutes after sunset. However, it lies just 3° above the horizon and sets quickly. You'll need a flat, unobstructed western horizon to spot Mercury this early.

Conditions improve daily, with Mercury appearing about 1° higher each evening relative to sunset. Mercury passes between Earth and our line of sight to Uranus February 13 and 14. On the 13th, Uranus lies 1° northeast of Mercury; the next night, Uranus stands 0.6° to the southwest. Glowing faintly at magnitude 5.9, Uranus will be a challenge to see in the twilight.

Mercury reaches greatest eastern elongation, and best visibility, February 23/24, when it lies 18° from the Sun. By this time, Mercury has faded to magnitude –0.5 and shows a 7"-diameter, half-lit disk through a telescope. The planet fades rapidly after greatest elongation, dimming to magnitude 0.3 by March 1. The disk then appears 9" across and

DISTANCE FROM THE SUN: 0.39 AU
ORBITAL PERIOD: 87.97 days
DIAMETER: 0.38 Earth
MASS: 0.06 Earth
DENSITY: 5.43 g/cc

FEBRUARY 06

S	M	T	W	T	F	S
			1	2	3	4
◑	6	7	8	9	10	11
●	13	14	15	16	17	18
19	20	◐	22	23	24	25
26	○	28				

5	The Moon passes 2° north of Mars, 5 P.M. EST	👁 🔭
6	Neptune is in conjunction with the Sun, 1 A.M. EST	
11	The Moon passes 4° north of Saturn, 10 A.M. EST	👁 🔭
14	Mercury passes 0.03° north of Uranus, 11 A.M. EST	🔭 🔭
17	Venus is at greatest brilliancy (magnitude −4.6), 3 P.M. EST	👁 🔭 🔭
20	The Moon passes 5° south of Jupiter, 3 A.M. EST	👁 🔭
21	The Moon passes 0.2° south of Antares, 4 P.M. EST	👁 🔭 🔭
23	Mercury is at greatest eastern elongation (18°), midnight EST	👁 🔭 🔭
24	The Moon passes 10° south of Venus, 4 P.M. EST	👁
26	The Moon passes 4° south of Neptune, 8 A.M. EST	🔭
28	The Moon passes 4° south of Mercury, 9 P.M. EST	👁 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

THE WINTER SKY holds lots of bright stars — be sure to find Sirius, Betelgeuse, and Rigel.
ASTRONOMY: ROEN KELLY

shows a slim, 23-percent-lit crescent through a scope.

Mercury has other evening appearances this year. It can be viewed from May 26 to July 11 and September 12 to November 3. The planet's best morning appearance occurs between November 15 and December 21, but you can also see it from January 1 to 12, March 19 to May 11, and July 26 to August 24. Mercury transits the Sun November 8 as seen from the Americas. See November for more on this event.

Learn the winter sky

A major signpost of the heavens, Orion the Hunter dominates the winter sky. Three closely spaced, 2nd-magnitude stars in a straight line form the unmistakable "belt" of Orion. Extending the imaginary line joining these stars to the upper right leads to Taurus the Bull and its orangish 1st-magnitude star, Aldebaran. Reverse the direction of your gaze to the belt's lower left, and you cannot miss Sirius the Dog Star — the brightest of them all — blazing at magnitude −1.5.

Now move perpendicular to the belt from its westernmost star to find Betelgeuse, the red supergiant star at the upper left of Orion. Continuing this line brings you to a pair of stars, Castor and Pollux, in Gemini the Twins.

Above Orion, and nearly overhead on winter evenings, is brilliant Capella in Auriga the Charioteer. Extending a line through the shoulders of Orion to the east leads you to Procyon in Canis Minor the Little Dog. Once you have these principal stars mastered, using an all-sky chart to discover the fainter constellations will be a lot easier. Take your time, and enjoy the journey.

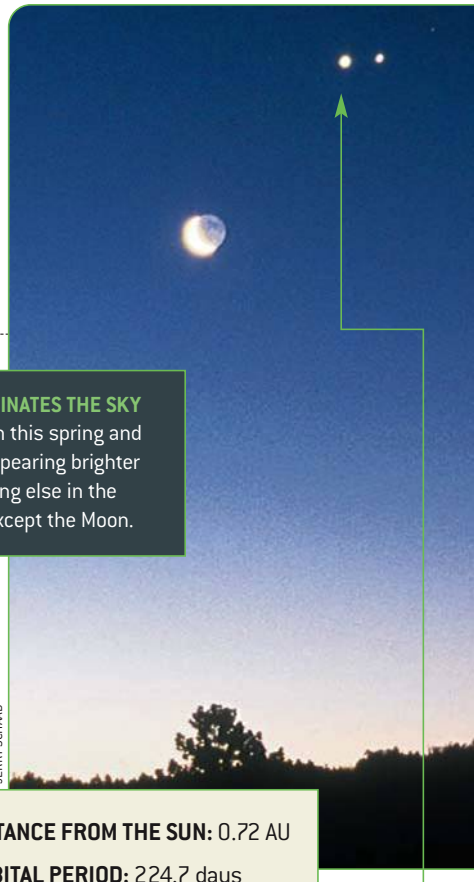
When to see Mercury in 2006

Evening Greatest elongation	Visible from	Peak altitude	Morning Greatest elongation	Visible from	Peak altitude
Feb. 23/24	Feb. 8 to March 6	11°	April 8	March 19 to May 11	4°
June 20	May 26 to July 11	10°	Aug. 6	July 26 to Aug. 24	10°
Oct. 16/17	Sept. 12 to Nov. 3	3°	Nov. 25	Nov. 15 to Dec. 21	12°

2006 near

Venus gleams at dawn

March provides celestial treats for both daytime and nighttime observers. For those who want to see the brightest point of light in the sky, get up shortly before dawn and look to the east, where brilliant Venus dominates the sky. For those who prefer bright-sky observing, head to Africa or Asia March 29, when our Moon will block the Sun from view.



JERRY SCHAAD

VENUS DOMINATES THE SKY before dawn this spring and summer, appearing brighter than anything else in the night sky except the Moon.

DISTANCE FROM THE SUN: 0.72 AU
ORBITAL PERIOD: 224.7 days
DIAMETER: 0.95 Earth
MASS: 0.82 Earth
DENSITY: 5.24 g/cc

Venus reaches the peak of its 2006 visibility in March, but it plays its "morning star" role for most of the year. After a 1-week stint in the evening sky at the start of 2006, Venus passes between the Sun and Earth January 13/14 and moves into the morning sky. The planet rises an hour before the Sun January 19 and reveals an exceedingly thin crescent that spans 60" through a telescope. By the end of January, the crescent has fattened to 10-percent illumination.

Venus brightens through mid-February, when it shines brightest at magnitude –4.6 and dominates the morning sky.

On March 25, Venus reaches greatest western elongation and rises 2 hours before the Sun. Through a telescope, it presents a 25"-diameter disk that appears half-lit.

During April, Venus crosses Aquarius, where it meets up with Uranus. On the 18th, Uranus lies 0.3° south of Venus, a rare line-of-sight chance to spot an inner planet near one of the distant gas giants.

When they meet, Venus shines 10,000 times brighter than Uranus. Through a telescope, Venus appears 19" across and 60-percent lit.

Venus rises due east during May as it crosses the constellation Pisces. On the 24th, a thin crescent Moon stands 4° away. When the crescent Moon passes Venus again in June, the planet lies in Taurus just 6° south of the Pleiades star cluster (M45). On June 22, the crescent Moon lies 9° northwest of Venus, and the following morning, the Moon appears 4° east of the Pleiades.

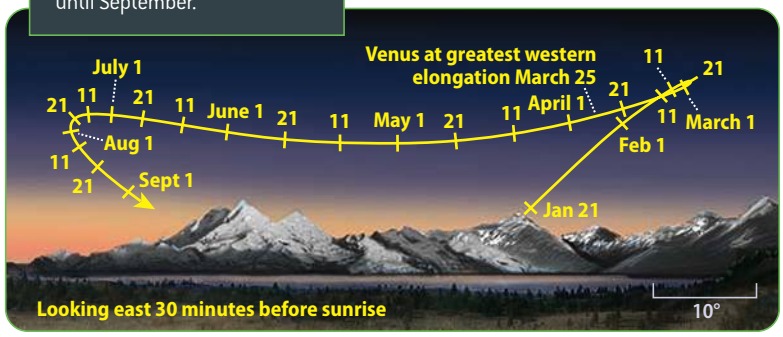
By August, Venus stands in Gemini the Twins. A telescope reveals the planet's almost fully illuminated disk, which measures 10" across. In mid-August, Venus lies near Mercury in our sky. Just 3° separate the planets August 7. On August 26, after Mercury has dipped back into the twilight glow, Saturn and Venus lie in the same telescopic field of view just a single Moon-width apart.

Twilight eventually swallows Venus in September. The planet tracks behind the Sun for the next 3 months, reappearing low in the southwest on evenings during the last half of December.

A totally grand eclipse

A total solar eclipse ranks among nature's most spectacular events. The Moon blocks direct sunlight, revealing the delicate glow of the Sun's outer atmosphere, the corona. March 29 brings the longest total eclipse over easily accessible land until 2009. Totality lasts up to 4 minutes and 7 seconds.

BRILLIANT VENUS comes into view in the morning sky in January and doesn't leave until September.



ASTRONOMY: TERRI FIELD

Calendar of events

MARCH 06

S	M	T	W	T	F	S
			1	2	3	4
5	◑	7	8	9	10	11
12	13	●	15	16	17	18
19	20	21	◐	23	24	25
26	27	28	○	30	31	

1	Uranus is in conjunction with the Sun, 6 A.M. EST	
6	The Moon passes 3° north of Mars, 2 A.M. EST	👁 🔭
10	The Moon passes 4° north of Saturn, 1 P.M. EST	👁 🔭
	Mars passes 7° north of Aldebaran, 7 P.M. EST	👁 🔭
11	Mercury is in inferior conjunction, 10 P.M. EST	
14	Penumbral lunar eclipse, 7 P.M. EST	👁 🔭 🔭
17	The Moon passes 0.3° north of Spica, 6 A.M. EST	👁 🔭 🔭
19	The Moon passes 5° south of Jupiter, 9 A.M. EST	👁 🔭
20	Equinox (northern spring/southern autumn begins), 1 P.M. EST	👁
	The Moon passes 0.3° south of Antares, 10 P.M. EST	👁 🔭 🔭
25	Venus is at greatest western elongation (47°), 2 A.M. EST	👁 🔭 🔭
	The Moon passes 6° south of Venus, 6 P.M. EST	👁 🔭
	The Moon passes 4° south of Neptune, 8 P.M. EST	🔭
26	Venus passes 1.9° north of Neptune, 4 P.M. EST	🔭
27	The Moon passes 1.4° south of Uranus, 10 A.M. EST	🔭
	The Moon passes 2° south of Mercury, noon EST	👁 🔭
29	Total solar eclipse, 5 A.M. EST	👁 🔭 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

A GHOSTLY CORONA and red prominences highlight the totally eclipsed Sun. FRED ESPENAK

The path of totality begins its journey across our globe at sunrise on the coast of Brazil. After a long hop across the Atlantic Ocean, the eclipse track crosses Niger, Chad, and Libya, with maximum eclipse occurring on the Chad-Libya border. The track then crosses Egypt and the Mediterranean Sea before reaching Turkey. Finally, it speeds across the Black and Caspian seas and on to Siberia, where the eclipse ends at sunset.

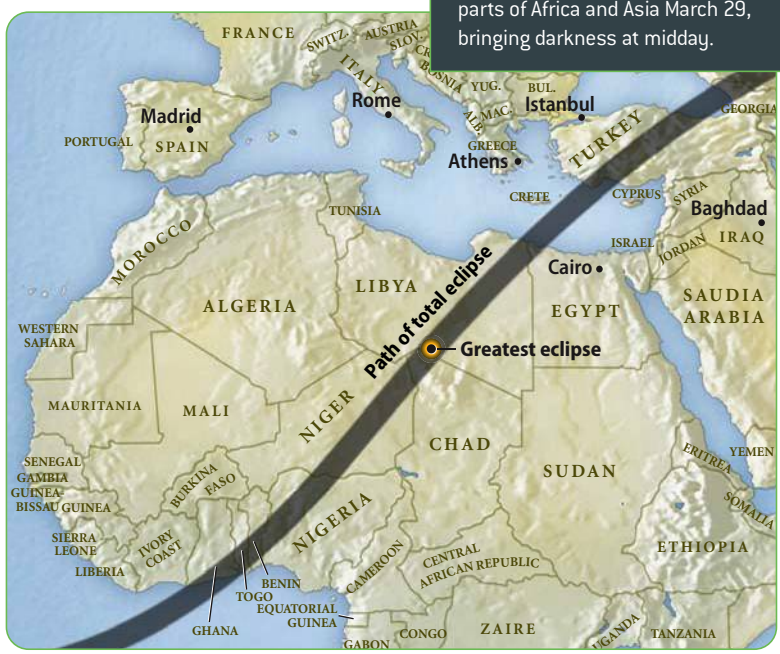
This eclipse should attract eclipse veterans and newcomers alike, thanks to the high probability of clear weather across much of the track. The ease of access to the Mediterranean provides additional appeal. The eclipse occurs with solar activity near a minimum, so expect the corona to stretch out more in the equatorial direction than during recent eclipses.

The eclipse begins when the Moon takes its initial, tiny bite out of the Sun's limb. During the next hour, the Moon, with its dark side facing Earth, moves over the Sun in a partial eclipse of growing magnitude. Ten minutes before totality, excitement ramps up. The landscape takes on a golden hue, and shadows become sharper. The temperature drops significantly. The Sun's disk looks like a smiley face set in a deepening blue sky. It's still too bright to view our star directly, but these 10 minutes race by.

All attention turns to the Sun as the final slivers of sunlight peek through valleys along the Moon's limb. A series of bright beads, known as Baily's beads, dwindle to a lone solitaire — the diamond ring. Suddenly, a black hole appears in the blue sky, surrounded by the exquisite solar corona. Voices ring out with delight as the intense moments of totality progress. The 4 minutes pass quickly, and the brightening of one edge foreshadows the spectacular ending of totality with another, usually more intense, diamond ring.

No sooner is this eclipse over than conversation turns to the next one. It occurs August 1, 2008, with the path of totality crossing the Arctic from northern Canada, through Greenland, and into northern Russia. It's a long time to wait, and weather prospects aren't as good as for the 2006 eclipse.

TOTALITY WASHES OVER observers along a thin path running through parts of Africa and Asia March 29, bringing darkness at midday.



ASTRONOMY: ROEN KELLY

2006 apr

The MOON stands STILL

The Moon takes center stage in April, putting on a display the likes of which we haven't seen in 18 years. This month, the Moon climbs higher in the northern sky than at any time since 1987. One consequence: The crescent Moon passes in front of the lovely Pleiades star cluster the evening of April 1.

Our celestial neighbor reaches its northernmost position in the sky in April and its southernmost location in September. This culmination of the Moon's 18.6-year-long orbital cycle gives everyone the opportunity to see the Moon rise and set significantly farther north and south than the Sun ever can. The event is called a "major lunar standstill."

One observational consequence of the standstill is that when the Moon rises at its northernmost extreme, it passes more nearly overhead for Northern Hemisphere observers than in other years. This is the situation with the winter Full Moon December 4. And when the Moon rises at its southern limit, it appears lower than at any recent time. The summer Full Moon June 11, for example, won't climb much above the southern horizon. From Chicago, the Moon stands just 19° high at its peak elevation. From London, it will be a mere 9° high.

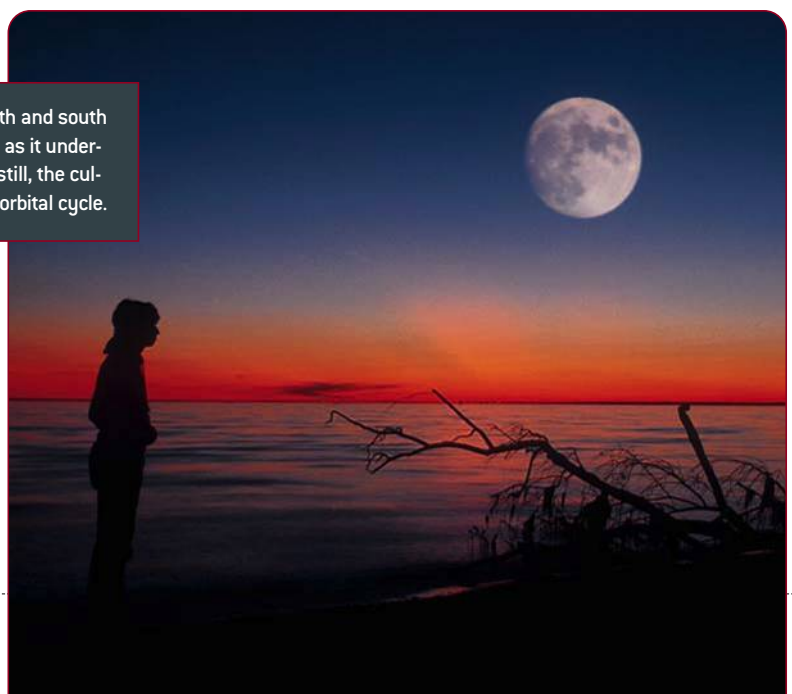
To understand why this occurs, let's first look at the variations in the Sun's rising and setting locations. Almost everyone is familiar with the changing seasonal location of sunrise and sunset. In March and September, the Sun rises due east and sets due west. Around the 21st of both months, the Sun lies on the celestial equator. On the June solstice, the Sun rises and sets at its most northerly extreme because it reaches its northernmost declination of 23.5°. On the December solstice, the Sun lies at a declination of –23.5° and rises far south of east and sets well south of west.

Throughout the year, the Sun's rising and setting points swing north and south, behaving like a pendulum. On the solstices, the rising and setting points change relatively little over a short period and could be described as a standstill of the Sun.

The Moon would follow the exact same path if its orbit were in the same plane as Earth's orbit, the ecliptic. But the Moon's orbit tilts 5.1° to the ecliptic. Joining the two points where the Moon's orbit crosses the ecliptic forms a line called the line of nodes. This line remains essentially fixed in space from one month to the next, but it does rotate around Earth slowly with a period of 18.6 years.

When the line of nodes aligns with the *solstice* points, the Moon lies on the ecliptic when it reaches those points. Consequently, the maximum northern and southern rising and setting points of the Moon match those of the Sun, and moonrise and moonset occur near the sunrise and sunset points. The tilt of the Moon's orbit causes the maximum deviation from the ecliptic to happen near the points where the ecliptic crosses the celestial equator.

However, when the line of nodes aligns with the *equinoxes*, the Moon's orbital tilt causes it to pass either 5.1° above or below the ecliptic at the northern and southern extremes. This is the situation in 2006. The Moon's declination thus varies from 28.6° to –28.6°. The major northern standstill occurs



THE MOON RISES well north and south of where it normally does as it undergoes a major lunar standstill, the culmination of an 18.6-year orbital cycle.

LARRY LANDOLFI

Calendar of events

APRIL 06

S	M	T	W	T	F	S
						1
2	3	4	◑	6	7	8
9	10	11	12	●	14	15
16	17	18	19	◐	21	22
23	24	25	26	○	28	29
30						

3	The Moon passes 4° north of Mars, 4 P.M. EDT	
6	The Moon passes 4° north of Saturn, 7 P.M. EDT	
8	Mercury is at greatest western elongation (28°), 3 P.M. EDT	
13	The Moon passes 0.3° north of Spica, 1 P.M. EDT	
15	The Moon passes 5° south of Jupiter, 11 A.M. EDT	
17	The Moon passes 0.2° south of Antares, 5 A.M. EDT	
18	Venus passes 0.3° north of Uranus, 8 A.M. EDT	
22	The Moon passes 4° south of Neptune, 5 A.M. EDT	
	Lyrid meteor shower peaks	
23	The Moon passes 1.2° south of Uranus, 10 P.M. EDT	
24	The Moon passes 0.5° south of Venus, 10 A.M. EDT	
26	The Moon passes 4° north of Mercury, 4 A.M. EDT	

LEGEND

	Events that can be viewed with the naked eye
	Events that can be viewed with binoculars
	Events that can be viewed with a telescope

A CRESCENT MOON PASSES the Pleiades star cluster April 1, the best of several such events visible from North America in 2006.

IVAN DRYER

April 4, and the major southern standstill arrives September 29. But the effects will be observable throughout 2006 and into 2007. The next major lunar standstill doesn't happen until 2024.

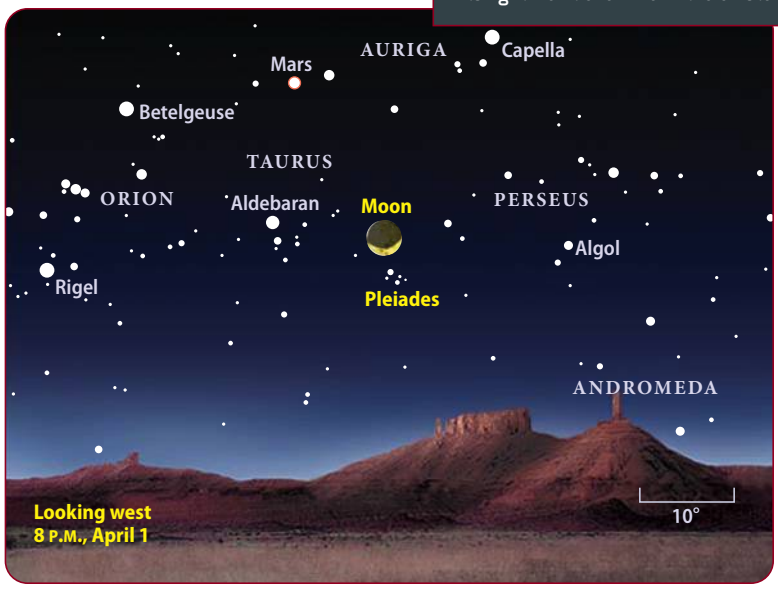
The Moon and Pleiades

The major lunar standstill has another noticeable effect on the Moon's path through the sky. When near a standstill, the Moon tracks farther north through the winter constellations Gemini and Taurus. This means its path takes it near the Pleiades star cluster (M45), the brightest object in Charles Messier's famous catalog of deep-sky wonders. The cluster lies 4° north of the ecliptic, so the Moon gets there only around the time of a standstill.

If a crescent Moon happens to be passing the Pleiades at a convenient time, backyard stargazers are in for a treat. The best event this year happens the evening of April 1, when a thin crescent Moon crosses the cluster. The timing favors viewers in North America, where the Moon lies in front of the cluster as darkness falls.

The good news: The Moon and Pleiades will be close each month for the next year or two. The slow shift of the lunar orbit means once these events begin, they keep going for a while. The bad news: You won't get many chances to see the two as close as they are this month, when the Moon shows a crescent phase. The Moon and the Pleiades won't always appear real close, and at least half the time, the Moon's brightness nearly drowns out M45.

LOOK FOR THE MOON just above the Pleiades after darkness falls April 1. The Moon appears 17-percent lit, so its light won't overwhelm the cluster.



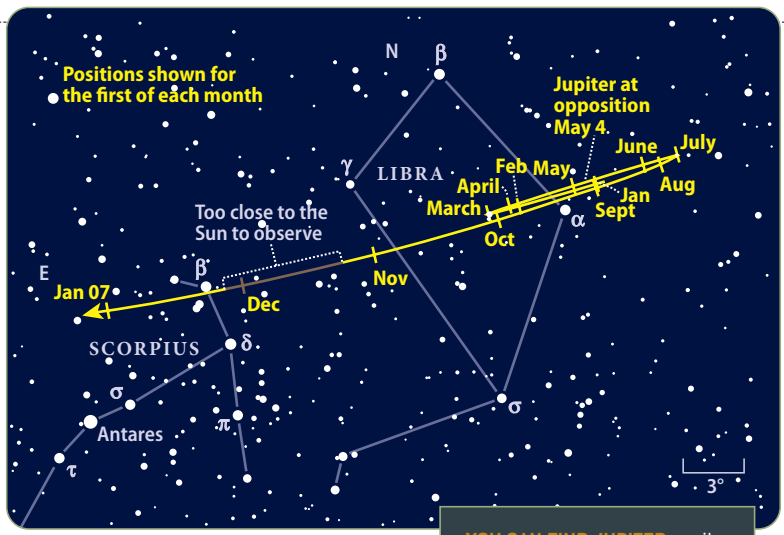
ASTRONOMY: TERRI FIELD

2006

may

Jupiter springs into action

Jupiter reaches best visibility in early May, when it lies opposite the Sun in our sky and remains conspicuous all night. At opposition, the giant planet also shines brightest and appears largest when viewed through a telescope. The king of planets lies in Libra during this apparition, easily dominating the relatively faint stars of this constellation.



ASTRONOMY: ROEN KELLY

YOU CAN FIND JUPITER easily this spring: Simply look for the brightest point of light in the evening sky.

Jupiter stands out on spring nights as the brightest point of light in the sky until Venus rises before dawn. The giant planet reaches the peak of its 2006 apparition May 4, when it lies opposite the Sun in our sky. Jupiter then lies closest to Earth, so it appears bigger and brighter than at any other time this year.

As the year starts, Jupiter lies in the morning sky among the stars of Libra. By early March, it rises before midnight and shines brilliantly at magnitude –2.2. By the end of April, the planet stands 1° north of Zubenelgenubi (Alpha [α] Librae), Libra's brightest star. At opposition May 4, Jupiter shines at magnitude –2.5 and spans 45". It appears low in the southeast as the sky grows dark. The best views will come around local midnight, when Jupiter lies about 40° above the southern horizon.

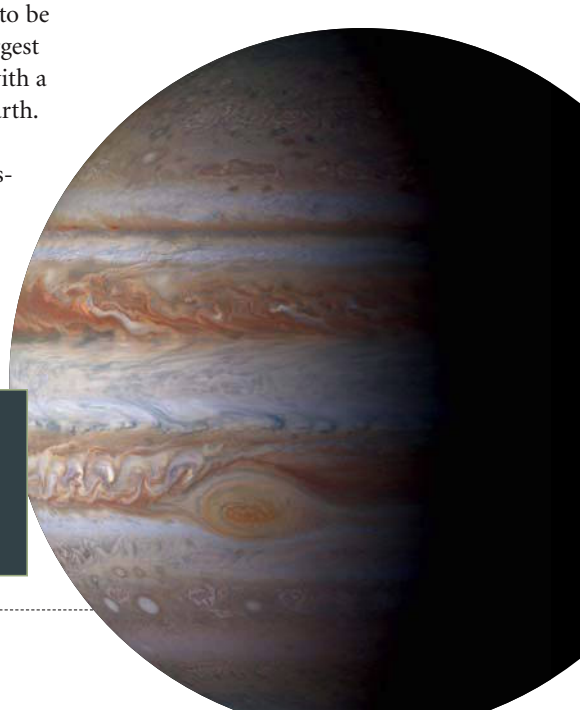
DISTANCE FROM THE SUN: 5.20 AU
ORBITAL PERIOD: 11.86 days
DIAMETER: 11.21 Earths
MASS: 317.83 Earths
DENSITY: 1.33 g/cc

Jupiter stays in the evening sky until early November, then it hides behind the Sun until reappearing in the morning sky in December.

Experienced planet-observers find Jupiter the most rewarding planet to observe. Jupiter rotates so quickly — completing one rotation in less than 10 hours — that it presents an ever-changing view of cloud features. Four bright moons change their positions relative to the planet every day, changes that, in some cases, can be seen in just a couple of hours. And, not to be overlooked, Jupiter is the largest planet in the solar system, with a diameter 11 times that of Earth. Consequently, however far Jupiter may be — and its distance varies by the diameter of Earth's orbit (186 million miles) — its disk remains impressive through any small telescope.

There are two key stages to viewing Jupiter. It starts with a simple look through the scope. Your first glance should provide a clear view of two dark equatorial belts. This, combined with the distinct flattening of Jupiter at the poles, is what most people first see.

The second stage reveals the rich details in Jupiter's atmosphere.



JUPITER HOLDS COURT during evenings this spring and summer, providing a tempting target to those with a small telescope. NASA/JPL/SSI

Calendar of events

MAY 06

S	M	T	W	T	F	S
	1	2	3	4	◐	6
7	8	9	10	11	12	○
14	15	16	17	18	19	◑
21	22	23	24	25	26	●
28	29	30	31			

2	The Moon passes 4° north of Mars, 7 A.M. EDT	👁 🔭
4	The Moon passes 4° north of Saturn, 5 A.M. EDT	👁 🔭
	Jupiter is at opposition, 11 A.M. EDT	👁 🔭 🔭
5	Eta Aquarid meteor shower peaks	👁
10	The Moon passes 0.3° north of Spica, 8 P.M. EDT	👁 🔭 🔭
12	The Moon passes 5° south of Jupiter, noon EDT	👁 🔭
14	The Moon passes 0.1° south of Antares, 11 A.M. EDT	👁 🔭 🔭
18	Mercury is in superior conjunction, 4 P.M. EDT	
19	The Moon passes 4° south of Neptune, 11 A.M. EDT	🔭
21	The Moon passes 1.0° south of Uranus, 6 A.M. EDT	🔭
24	The Moon passes 4° north of Venus, 4 A.M. EDT	👁 🔭
25	Mars passes 5° south of Pollux, 1 A.M. EDT	👁 🔭
30	The Moon passes 3° north of Mars, 11 P.M. EDT	👁 🔭
31	The Moon passes 4° north of Saturn, 5 P.M. EDT	👁 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

THE SPRING SKY affords a fine view out of the Milky Way's plane toward galaxy-rich Virgo and Leo. *ASTRONOMY:* ROEN KELLY

Although the planet appears tiny relative to the pictures you see in magazines, the eye can see detail if you're patient. Let your eye become accustomed to the bright spot of Jupiter in the eyepiece, then look for subtle features above, below, and between the dark belts. This patient viewing marks the difference between looking and observing.

Two things at least partially under your control affect the visibility of these features. If you have a reflector, make sure your telescope is properly collimated. This boosts the contrast noticeably. Because the jovian atmosphere presents many low-contrast features, a poorly collimated scope will miss them. Earth's turbulent atmosphere hides small features as well. Wait for moments of steady seeing, which occur most often when Jupiter lies high in the sky. Still moments may be fleeting, but they reveal many atmospheric features.

Learn the spring sky

The Big Dipper swings high overhead on spring evenings as a convenient signpost for the spring sky. Follow the arc of stars forming the "handle" of the Big Dipper away from the "bowl," and you will land on brilliant Arcturus. This orangish star dominates the spring sky in the kite-shape constellation Boötes. Well to the west of Boötes lies Leo the Lion. You can find Leo's brightest star, Regulus, by heading south from the two end stars in the Dipper's bowl.

To the southeast of Leo is the "realm of the galaxies" and the constellation Virgo the Maiden. Virgo's brightest star, Spica, shines at magnitude 1.0.

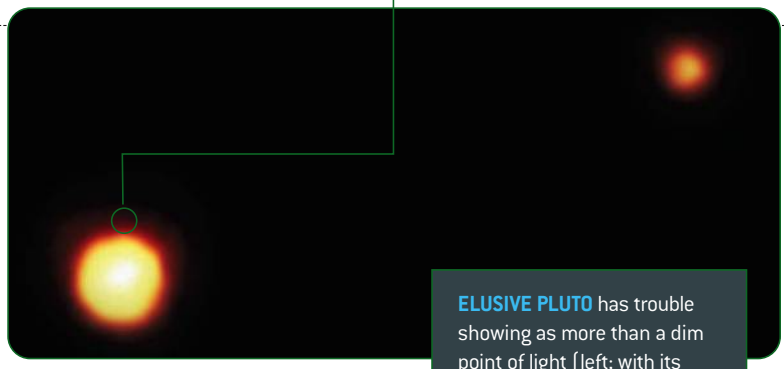
Midway between Arcturus and Vega, the bright "summer" star rising in the northeast, is a region where no star shines brighter than 2nd magnitude. A semicircle of stars represents Corona Borealis, and adjacent to it is a large region that houses Hercules. Here we find the northern sky's best globular cluster, M13. A naked-eye object from a dark site, it is spectacular when viewed through a telescope.

2006 Jun

Spying Pluto's faint glow

DISTANCE FROM THE SUN: 39.24 AU
ORBITAL PERIOD: 247.68 years
DIAMETER: 0.19 Earth
MASS: 0.002 Earth
DENSITY: 1.75 g/cc

The first month of summer provides views near and far, of objects bright and faint. The periodic comet Schwassmann-Wachmann 3 should be an easy naked-eye target when it comes closest to the Sun in early June. At the other end of the scale, Pluto has such a small diameter and lies so far from the Sun that you'll need an 8-inch scope to see it.



NASA/ESA

ELUSIVE PLUTO has trouble showing as more than a dim point of light (left; with its moon, Charon) even with Hubble. Count yourself lucky if you can glimpse the planet.

Tracking down Pluto provides a nice challenge for anyone with an 8-inch or larger telescope. The distant planet lies in the constellation Serpens Cauda throughout 2006 and glows dimly at magnitude 13.9. It reaches the peak of its apparition at opposition June 16.

Opposition usually marks the best time to view a planet, but in Pluto's case, that's not so important. The outermost planet lies so far away — 2.9 billion miles on average — that it remains essentially the same brightness all year. You can spot Pluto about as easily a few months before or after opposition, as long as you know where to look.

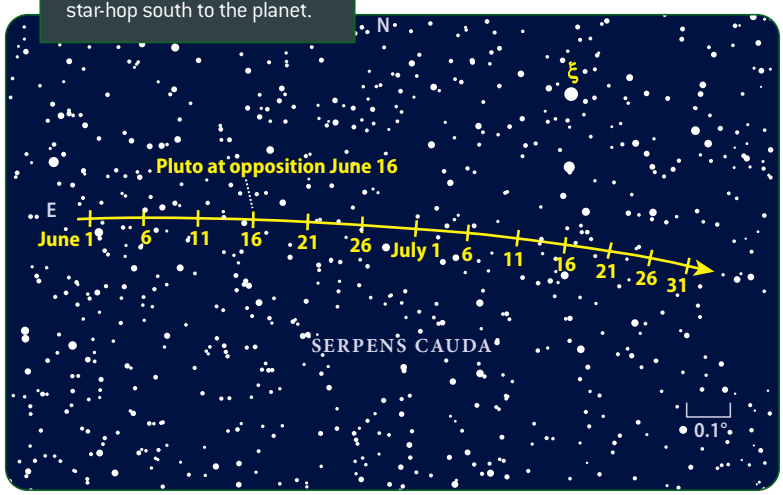
The first step in finding Pluto is identifying the right field of view. Modern go-to telescopes make this task easy. Visual confirmation is the challenge, and an accurate star chart showing stars down to 14th magnitude will help. Seeing Pluto itself requires a dark, moonless sky and good atmospheric transparency.

If you don't have a computer-controlled scope, the easiest way to locate the right field of view is to wait until Pluto lies near a fairly bright star. That happens twice this year. Pluto passes close to the 3.5-magnitude star Xi (ξ) Serpentis and also a 7th-magnitude star located 1.2° east of Xi. Both appear conspicuous through a finder scope.

On May 29, Pluto lies due south and in the same field of view as the 7th-magnitude star. You can use this star as a guide to finding Pluto for several nights because it remains in the same low-power field.

Pluto moves slowly westward each night until it reaches a point due south of Xi Serpentis July 16 and 17. There's a 6th-magnitude star situated 10' due south of Xi, and Pluto lies the same distance farther south of this star. The best way to identify which faint dot is actually Pluto is to track its motion over a few nights, either by making a simple sketch each night or using a sensitive imaging system like a CCD camera.

THE KEY TO FINDING PLUTO is to locate the 3.5-magnitude star Xi (ξ) Serpentis, then star-hop south to the planet.



ASTRONOMY: ROEN KELLY

A summer comet

Comets with relatively short periods rarely put on good displays. Comet 1P/Halley is the exception that proves the rule: It almost always looks impressive when it returns to Earth's vicinity on its 86-year schedule. Other short-period comets occasionally brighten

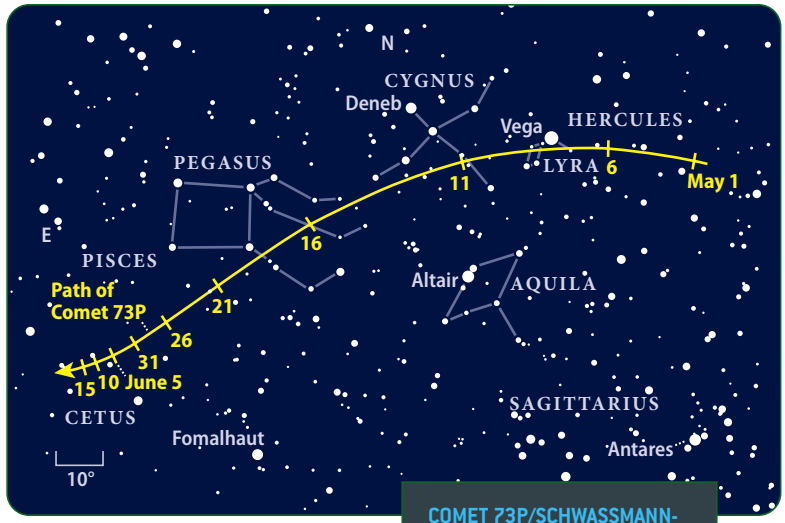
JUNE 06

S	M	T	W	T	F	S
				1	2	◑
4	5	6	7	8	9	10
●	12	13	14	15	16	17
◐	19	20	21	22	23	24
○	26	27	28	29	30	

7	The Moon passes 0.1° north of Spica, 5 A.M. EDT	👁 🔭
8	The Moon passes 5° south of Jupiter, 3 P.M. EDT	👁 🔭
10	The Moon passes 0.1° south of Antares, 7 P.M. EDT	👁 🔭
15	The Moon passes 3° south of Neptune, 5 P.M. EDT	🔭
16	Pluto is at opposition, 1 P.M. EDT	🔭
17	The Moon passes 0.6° south of Uranus, 5 A.M. EDT	🔭
	Mars passes 0.6° north of Saturn, 7 P.M. EDT	👁 🔭
20	Mercury is at greatest eastern elongation (25°), 4 P.M. EDT	👁 🔭
	Mercury passes 6° south of Pollux, 7 P.M. EDT	👁 🔭
21	Solstice (northern summer/southern winter begins), 8 A.M. EDT	👁
22	The Moon passes 6° north of Venus, 11 P.M. EDT	👁 🔭
27	The Moon passes 5° north of Mercury, 10 A.M. EDT	👁 🔭
28	The Moon passes 3° north of Saturn, 7 A.M. EDT	👁 🔭
	The Moon passes 2° north of Mars, 5 P.M. EDT	👁 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope



ASTRONOMY: ROEN KELLY

COMET 73P/SCHWASSMANN-WACHMANN 3 rides high in the northern sky when it peaks in brightness during May and June.

enough to see with the naked eye, but most remain binocular or, more often, telescopic objects. The truly great comets invariably have long periods and are making their first recorded visit to the inner solar system.

Yet, this year brings a periodic comet that should brighten to 1st magnitude. Comet 73P/Schwassmann-Wachmann 3 reaches perihelion (its closest approach to the Sun) June 7, when it comes within 87 million miles of our star. As the comet approaches the Sun, the Sun's heat will warm the surface of its dirty-snowball nucleus and liberate gas and dust.

The gas and dust will create a surrounding cloud and two tails, all of which should be apparent. Although Schwassmann-Wachmann 3 lies closest to the Sun in June, it will appear brighter in May, when it comes closest to Earth. At closest approach May 13, the comet lies just 7 million miles from our home planet. That's closer than Comet Hyakutake came in 1996. The comet should be visible to the naked eye from April through much of July.

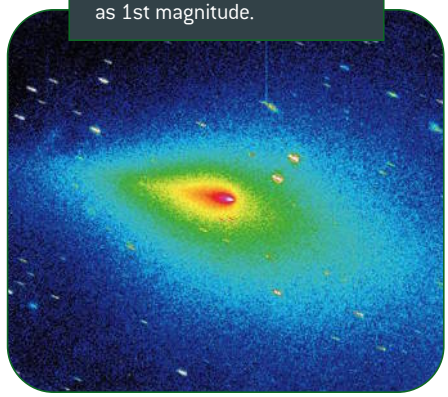
The comet couldn't be much better-placed for observers in the Northern Hemisphere. It treks rapidly through Hercules, Lyra, Cygnus, Pegasus, and Pisces at its brightest during May, and it's positioned high in the sky after midnight. Once June rolls around, it moves into Cetus and becomes harder for northerners to see before dawn. That's when those in the Southern Hemisphere will get a better look.

To see it at its best, head to a dark observing site. This will increase the contrast between sky and comet, giving you a better view. Avoid the week around the May 13 Full Moon.

The comet's close pass to Earth also means we should get a good tail view. You can expect to see two tails: a yellowish one of dust, and a blue-white tail of ionized gas. The dust tail gets pushed away from the comet's nucleus by the gentle force of the Sun's radiation pressure, and it should curve slightly. The straight gas tail gets carried away from the Sun by the rapidly moving solar wind.

The tails should grow long because of the comet's nearness to Earth and a favorable viewing geometry.

A BRIGHT PERIODIC COMET named Schwassmann-Wachmann 3 will put on a nice display during May and June, when it glows as bright as 1st magnitude.



ESO

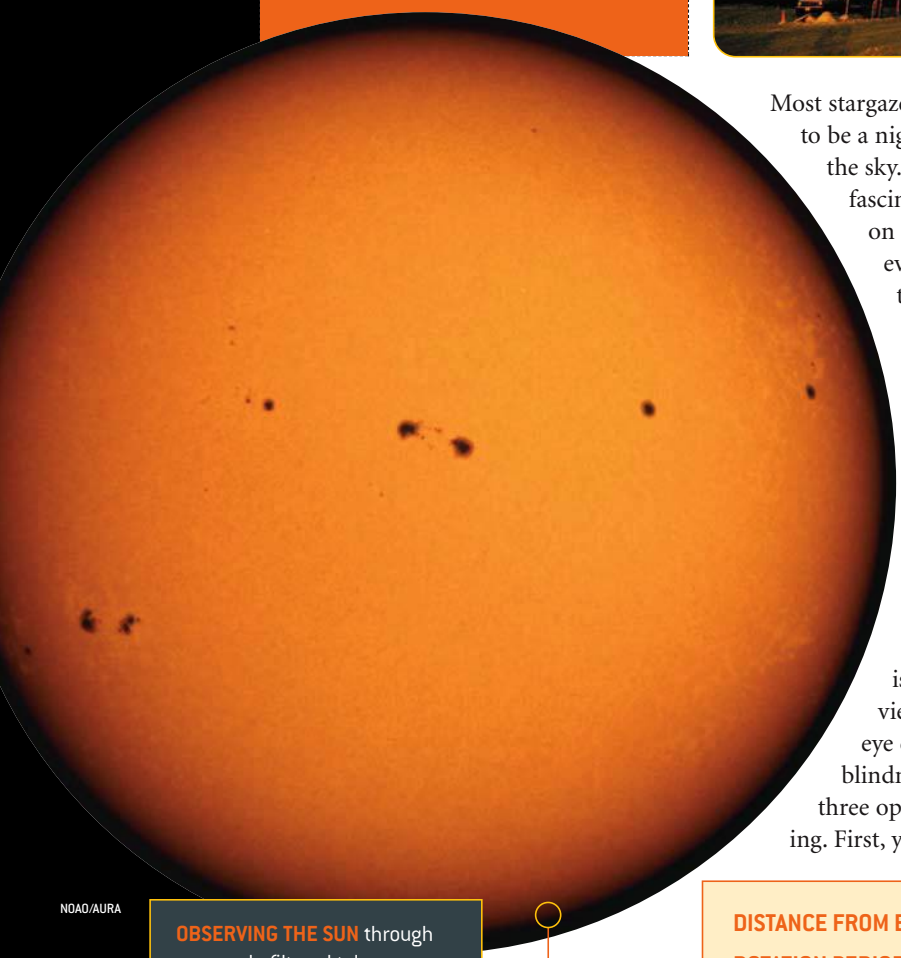
jul 2006

Spotlight on the SUN

Summer offers a great opportunity to view our nearest star. The Sun stays high in the sky for extended periods, and midday clouds are less frequent than at other times of the year. Through a properly filtered telescope, you can expect to see a few dark blemishes — sunspots — even during this year of solar minimum.

MARVIN NAUMANN

BEAUTIFUL STREAMERS of green light shimmer in the night sky, an auroral display that can be traced back directly to solar activity.



NOAO/AURA

OBSERVING THE SUN through a properly filtered telescope provides a great way to track changing sunspot numbers during the next several years.

Most stargazers think you have to be a night owl to view the sky. Not so. The most fascinating star of all is on prominent display every clear day: the Sun. It is an attractive target because it's the only star that shows any detail.

The one disadvantage to solar observing is the need to take safety precautions. The Sun is so bright that viewing it can cause eye damage and even blindness. You have three options for observing. First, you can project the Sun's image onto a white card. Point your telescope toward the Sun by minimizing the scope's shadow on the ground. Never put your eye near the eyepiece. The retina has no pain receptors, and blindness can result in an instant. Second, place a good solar filter over the front end of your telescope. Third, buy a specially made solar telescope.

The first things you'll see on the Sun are sunspots. This year, you won't see as many as usual. The Sun goes through an 11-year activity cycle during which the number of sunspots ebbs and flows. Astronomers predict the next minimum in activity should come in late 2006.

Although you may not see a lot of spots, now's a good time to start recording how many you do see. Observe the Sun once a month and count the sunspots. If you continue this for several years, you can chart the rise in activity that precedes the next solar maximum. Astronomers predict this will come in 2011.

DISTANCE FROM EARTH: 1.00 AU
ROTATION PERIOD: 24.27 days
DIAMETER: 109.3 Earths
MASS: 333,400 Earths
DENSITY: 1.41 g/cc
SURFACE TEMPERATURE: 10,000° F

Calendar of events

JULY 06

S	M	T	W	T	F	S
						1
2	◑	4	5	6	7	8
9	●	11	12	13	14	15
16	◐	18	19	20	21	22
23	24	○	26	27	28	29
30	31					

1	Asteroid Pallas is at opposition, 4 P.M. EDT	
2	Venus passes 4° north of Aldebaran, 4 P.M. EDT	
4	The Moon passes 0.1° south of Spica, 1 P.M. EDT	
5	The Moon passes 5° south of Jupiter, 10 P.M. EDT	
8	The Moon passes 0.2° south of Antares, 4 A.M. EDT	
12	The Moon passes 3° south of Neptune, midnight EDT	
14	The Moon passes 0.4° south of Uranus, 7 P.M. EDT	
18	Mercury is in inferior conjunction, 3 A.M. EDT	
22	Mars passes 0.7° north of Regulus, 2 A.M. EDT	
	The Moon passes 6° north of Venus, 8 P.M. EDT	
27	The Moon passes 1.1° north of Mars, 1 P.M. EDT	
31	The Moon passes 0.4° south of Spica, 9 P.M. EDT	

LEGEND	
	Events that can be viewed with the naked eye
	Events that can be viewed with binoculars
	Events that can be viewed with a telescope

THE SUMMER SKY provides short nights and pleasant temperatures for gazing at the Milky Way. *ASTRONOMY:* ROEN KELLY

Solar activity isn't just a playground for daytime observers. If you're lucky, you can see an additional aspect of the Sun's activity under a dark sky. Charged particles from our star continually bombard Earth's magnetic field, which funnels the particles to Earth's polar regions. There, the particles interact with molecules in the atmosphere to create ethereal aurorae — the northern and southern lights.

Despite the impending solar minimum, some auroral display typically appears every clear night under the auroral band, which crosses Alaska, northern Canada, Iceland, Scandinavia, and northern Russia. Low solar activity is more likely to show itself with fewer aurorae at southerly latitudes. Still, as the brilliant displays in late 2003 proved, you don't have to be at solar maximum to have stunning aurorae.

Learn the summer sky

The splendor of the Milky Way highlights the richness of the summer sky. Stretching from the northern horizon in Perseus, through the cross-shape constellation of Cygnus overhead, and down to Sagittarius in the south, the Milky Way is packed with star clusters and nebulae.

The first star to appear after sunset is Vega in Lyra the Harp, nearly straight overhead. Vega forms one corner of the Summer Triangle, a familiar asterism of three bright stars. To the east of Vega lies the triangle's faintest star: Deneb in Cygnus the Swan. Deneb marks the tail of this graceful bird, a cross of stars represents its outstretched wings, and the base of the cross denotes its head, which is marked by the incomparable double star, Albireo. Also notice the Milky Way splits into two parts in Cygnus. Interstellar dust blocking starlight from beyond creates this giant rift.

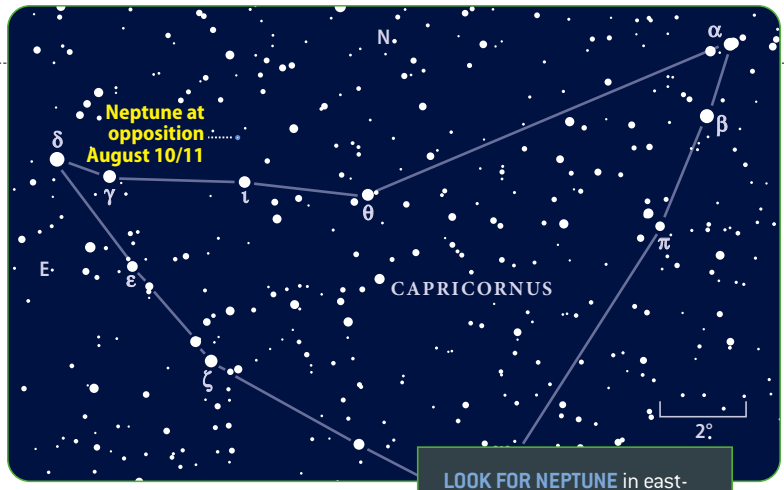
Altair, the third star of the Summer Triangle, stands in the middle in terms of brightness. It lies 17 light-years from Earth and is Aquila the Eagle's luminary.

Hugging the southern horizon, Sagittarius and Scorpius reside in the thickest part of the Milky Way. Antares is a red supergiant star whose name means "rival of Mars" and derives from its similar color and brightness.

aug 2006

A fine year for NEPTUNE

Two objects just beyond naked-eye visibility come to the fore this month. The distant gas-giant planet Neptune reaches opposition and best visibility August 10/11. One day later, minor planet Ceres passes the same orbital mark. Discovering these objects was a triumph for 19th-century astronomers, who vastly expanded the scope of our solar system.



ASTRONOMY: ROEN KELLY

LOOK FOR NEPTUNE in eastern Capricornus, about 1° north of the 4th-magnitude star Iota (ι) Capricorni.

Neptune has spent the past 8 years within the borders of Capricornus, and it has 4 more to go before it reaches the next stop on its orbital journey, Aquarius. Each year, it performs a small retrograde loop when Earth overtakes the lumbering giant as the two planets loop around the Sun. On August 10/11 this year, midway along this westerly retrograde path, Neptune reaches opposition. It then lies 1.4° north of the 4.3-magnitude star Iota (ι) Capricorni. Iota lies slightly less than midway between Theta (θ) and Delta (δ) Cap, the stars that mark the mid-point and the eastern end of the constellation, respectively.

On July 14, about a month before its opposition, Neptune looks like a double star because it lies so close to an 8th-magnitude field star. For a few days on either side of this date, watch to see Neptune move past the star. On August 28, you'll notice four "stars" in a straight line due north of Iota. Neptune is the third one heading north. A few days on either side of this date, the line will look crooked — with Neptune being the one out of line. Binoculars mounted on a tripod will show these stars easily. The apparent alignment makes Neptune easy to identify.

Today, telescopic views of Neptune remind us of the Voyager 2 images sent back in 1989 of the planet. Neptune's deep blue atmosphere, a result of red light being absorbed, shows as a blue-gray hue through ground-based telescopes.

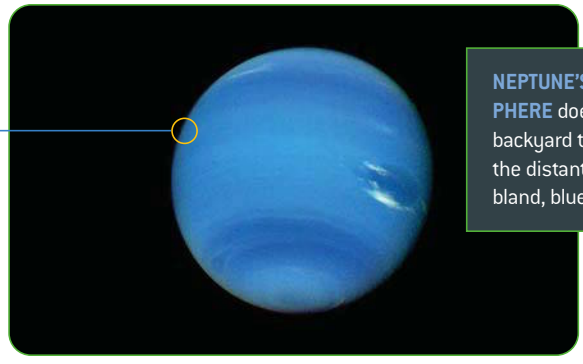
The planet's blue sky looked eerily like Earth's when those first Voyager images were relayed back to NASA. White, wispy clouds looked like high-altitude cirrus on Earth. You won't see any of these details on Neptune through a telescope, but it will reveal Neptune's 2.3"-diameter disk, which betrays its planetary status.

An asteroid goes fishing

Asteroids appear like stars through Earth-based telescopes. In fact, the name *asteroid* means "starlike." Astronomers have discovered several hundred thousand, most too faint to be seen with a typical backyard scope. Several, however, glow bright enough to be seen through binoculars or small telescopes.

The largest asteroid is Ceres, measuring 595 miles in diameter.

DISTANCE FROM THE SUN: 30.05 AU
ORBITAL PERIOD: 164.79 years
DIAMETER: 3.88 Earths
MASS: 17.15 Earths
DENSITY: 1.64 g/cc



NASA/JPL

NEPTUNE'S DYNAMIC ATMOSPHERE doesn't show up in backyard telescopes. Instead, the distant gas giant shows a bland, blue-gray disk.

AUGUST 06

S	M	T	W	T	F	S
		1	◑	3	4	5
6	7	8	●	10	11	12
13	14	◐	16	17	18	19
20	21	22	○	24	25	26
27	28	29	30	◑		

2	The Moon passes 5° south of Jupiter, 8 A.M. EDT	👁 🔭
4	The Moon passes 0.4° south of Antares, 2 P.M. EDT	👁 🔭 🔭
6	Mercury passes 9° south of Pollux, 8 A.M. EDT	👁
	Mercury is at western elongation (19°), 9 P.M. EDT	👁 🔭 🔭
7	Saturn is in conjunction with the Sun, 8 A.M. EDT	
8	Venus passes 7° south of Pollux, 4 A.M. EDT	👁
9	The Moon passes 3° south of Neptune, 8 A.M. EDT	🔭
11	Neptune is at opposition, 1 A.M. EDT	🔭 🔭
	The Moon passes 0.3° south of Uranus, 2 A.M. EDT	🔭 🔭
12	Asteroid Ceres is at opposition, 11 A.M. EDT	🔭 🔭
	Perseid meteor shower peaks	👁
20	Mercury passes 0.5° north of Saturn, 7 P.M. EDT	👁 🔭 🔭
21	The Moon passes 3° north of Venus, 11 P.M. EDT	👁 🔭
25	The Moon passes 0.6° south of Mars, 10 A.M. EDT	👁 🔭 🔭
26	Venus passes 0.07° north of Saturn, 7 P.M. EDT	👁 🔭 🔭
28	The Moon passes 0.5° south of Spica, 4 A.M. EDT	👁 🔭 🔭
29	The Moon passes 5° south of Jupiter, 9 P.M. EDT	👁 🔭
31	The Moon passes 0.5° south of Antares, 10 P.M. EDT	👁 🔭 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

K. BOLAM

ASTEROID CERES orbits the Sun between Mars and Jupiter. In January 1801, the 595-mile-wide space rock became the first such minor planet ever discovered.

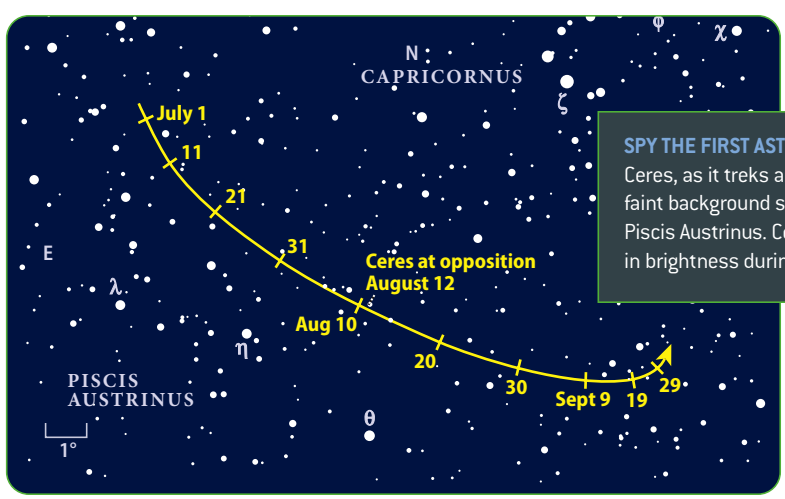
It reaches opposition and peak visibility August 12, when it glows at magnitude 7.6. It lies well south of the ecliptic in Piscis Austrinus the Southern Fish, west of this often-neglected constellation's brightest star, Fomalhaut. The constellation's low altitude, as seen from much of the Northern Hemisphere, and the lack of nearby bright stars to guide you will make finding Ceres more of a challenge than usual. The chart below should help you get there.

Vesta is the brightest asteroid, despite being only 320 miles in diameter. It reaches magnitude 6.2 at opposition January 5, when it lies in Gemini the Twins. On Christmas Eve of 2005, just prior to its opposition, Vesta passes less than 0.5° from Delta (δ) Geminorum. You can easily track its motion each night with binoculars. On February 2 and 3, Vesta crosses central Gemini and passes near a pair of 6th-magnitude stars located southwest of Epsilon (ε) Gem. Several other asteroids come within easy reach of backyard telescopes. The table above gives positions and magnitudes for the brightest.

Perhaps the biggest asteroid news of 2004 was the discovery of 2004 MN_4, and the realization it will pass just 4 Earth-diameters from us April 13, 2019. For a few hours, this 1,000-foot-wide lump of solid rock will reach 3rd magnitude and cross an amazing 42° of sky every hour. This event, perhaps more than any other in the 21st century, will bring home the necessity of investing in space travel. Humanity's only hope of long-term survival is a space program that can deflect potential impactors away from Earth.

Asteroids in 2006

Name	Opposition	Constellation	Magnitude
4 Vesta	Jan. 5	Gemini	6.2
2 Pallas	July 1	Hercules	9.5
15 Eunomia	July 29	Capricornus	8.3
6 Hebe	Aug. 4	Aquarius	7.8
1 Ceres	Aug. 12	Piscis Austrinus	7.6
7 Iris	Nov. 14	Aries	6.8



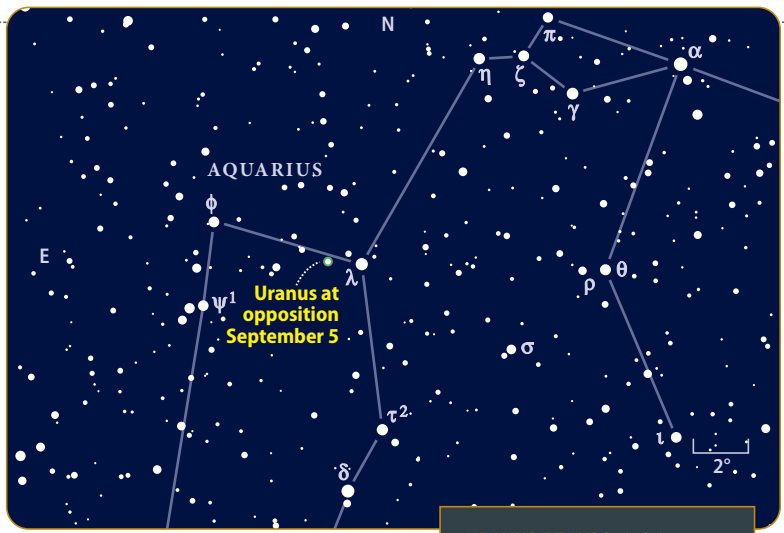
ASTRONOMY: ROEN KELLY

SPY THE FIRST ASTEROID, Ceres, as it treks among the faint background stars of Piscis Austrinus. Ceres peaks in brightness during August.

2006 sep

Uranus sings the blues

To see this month's annular eclipse, you have to be in the right place at the right time — along a thin path from northern South America to south of Africa September 22. But anyone can see this month's more subtle highlight: Uranus at its peak. The gas-giant planet reaches naked-eye visibility and shows a striking blue-green hue through a telescope.



ASTRONOMY: ROEN KELLY

URANUS PEAKS in brightness and apparent size when it reaches opposition September 5 in eastern Aquarius.

Uranus and Neptune are the twins of the solar system. They have about the same diameter (4 times bigger than Earth's) and mass (Uranus contains 15 Earths, and Neptune, 17). Both were discovered using telescopes, a result of being the only larger-than-Earth planets beyond Saturn — the edge of the classically known solar system. And both lie so far from Earth they move relatively short distances along their orbits each year.

However, because Uranus is closer to Earth than Neptune, Uranus creeps eastward at a faster pace. In 1993, both planets were within a few degrees of each other in Sagittarius the Archer and reached opposition just 11 hours apart. Since then, Neptune has pushed its way into Capricornus the Sea Goat, while Uranus has covered almost twice that distance, having ended up in Aquarius the Water-bearer. This is where Uranus reaches opposition September 5.

Uranus rises around local midnight in early July, when it lies 3° east of the 4th-magnitude star Lambda (λ) Aquarii. By August 8, Uranus will have moved westward enough to be in the same vicinity as 81 Aquarii. Glowing at magnitude 5.7, the planet appears slightly brighter than the star, which lies less than 0.1° north of Uranus.

Uranus continues the westerly drift of its retrograde loop each day. At opposition, it lies 1.2° east of Lambda Aqr. By October 10/11, its motion has carried it to a spot just 0.5° south of Lambda.

The westerly motion comes to a halt November 20, when Uranus resumes its normal eastward movement. It remains within 1° of Lambda Aqr throughout autumn. Its daily motion relative to Lambda will be easy to follow through binoculars.

Through a telescope, Uranus appears distinctly blue-green. At opposition, the disk measures a meager 3.7" in diameter. Blame the planet's great distance — it lies 1.8 billion miles from Earth.

DISTANCE FROM THE SUN: 19.20 AU
ORBITAL PERIOD: 84.01 years
DIAMETER: 4.01 Earths
MASS: 14.54 Earths
DENSITY: 1.27 g/cc

NASA/JPL

BLUE-GREEN URANUS shows its distinct color through backyard telescopes, but that's about all the detail you can hope to see.

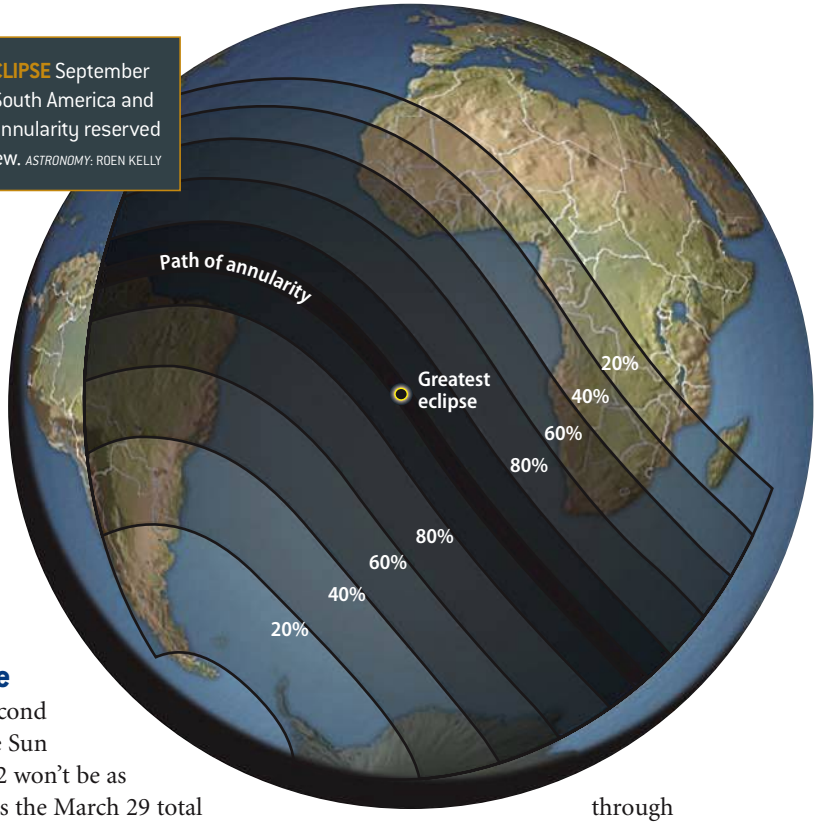
SEPTEMBER 06

S	M	T	W	T	F	S
					1	2
3	4	5	6	●	8	9
10	11	12	13	◐	15	16
17	18	19	20	21	○	23
24	25	26	27	28	29	◑

1	Mercury is in superior conjunction, 1 A.M. EDT	
5	Uranus is at opposition, 7 A.M. EDT	👁 🔭
	The Moon passes 3° south of Neptune, 6 P.M. EDT	🔭
	Venus passes 0.8° north of Regulus, 7 P.M. EDT	👁 🔭
7	The Moon passes 0.4° south of Uranus, 11 A.M. EDT	🔭
	Partial lunar eclipse, 3 P.M. EDT	👁 🔭
15	Mercury passes 0.2° south of Mars, 5 P.M. EDT	👁 🔭
18	The Moon passes 2° north of Saturn, 11 P.M. EDT	👁 🔭
22	Annular solar eclipse, 8 A.M. EDT	👁 🔭
	Equinox (northern autumn/southern spring begins), midnight EDT	👁
23	The Moon passes 1.8° south of Mercury, midnight EDT	👁 🔭
24	The Moon passes 0.5° south of Spica, 10 A.M. EDT	👁 🔭
26	The Moon passes 5° south of Jupiter, noon EDT	👁 🔭
27	Mercury passes 1.3° north of Spica, 11 A.M. EDT	👁 🔭
28	The Moon passes 0.5° south of Antares, 4 A.M. EDT	👁 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope



A PARTIAL ECLIPSE September 22 reaches South America and Africa, with annularity reserved for a lucky few. *ASTRONOMY:* ROEN KELLY

Ring of fire

The year's second eclipse of the Sun September 22 won't be as spectacular as the March 29 total eclipse, but it still should be breathtaking for those positioned on the central path. Seen from there, the Moon will pass directly in front of the Sun as it did in March, but, because the Moon now lies as far from Earth as possible, it can't block the entire solar disk. Instead, a ring of sunlight remains visible at maximum eclipse. Such eclipses are called "annular," after the Latin word for ring, *anulus*.

Because the Sun never disappears from view, you must take precautions to view an annular eclipse, either by projecting the Sun's image or using a good solar filter to observe it. (See the July section on solar observing, pages 62–63, for more details on viewing the Sun.)

The eclipse's track almost looks like a continuation of that from the April 2005 annular/total eclipse. That one ended as an annular eclipse at sunset in east-central Venezuela. The path of annularity September 22 starts at sunrise a couple of hundred miles east of there in Guyana. It then heads through Suriname and French Guiana before heading into the Atlantic Ocean. Unlike the April 2005 eclipse, this one offers a long period of annularity. Even at the beginning of the track in South America, observers can expect to see up to 5 minutes of annularity on the center line. Maximum eclipse occurs over the south Atlantic, where the ring of sunlight will last for 7 minutes and 9 seconds.

The associated partial eclipse extends thousands of miles from the center line. People on many of the Caribbean islands as well as in most of South America will see a partial eclipse during the early morning hours. People in western and southern Africa will see a partial eclipse around noon or shortly thereafter.

BRIAN DAY

A RING OF FIRE will greet observers in northern South America the morning of September 22, but you'll have to be in the mid-Atlantic to see the entire 7-minute show.

oct 2006

The ZODIAC lights up

You might think brightness is a key requirement for seeing something with the naked eye, but that's not always the case. On mornings in early and late October, viewers blessed with a dark sky can glimpse the ghostly glow of the zodiacal light. Half an hour before twilight begins, look to the east for a faint pyramid of light mimicking the approaching dawn.

Debris litters the solar system. Most of it consists of fine dust particles, ranging in size from pebbles down to a tiny fraction of the width of a human hair. Some of this interplanetary dust derives from comets.

Every time one of these dirty snowballs nears the Sun, solar heat warms the nucleus. This causes the comet's ices to sublimate, turning directly to gas and carrying away dust in the process. With innumerable comets making many trips through the inner solar system, you get lots of dust.

Most of the rest of the dust comes from the hundreds of thousands of asteroids that populate the region between the orbits of Mars and Jupiter. These rocky objects occasionally collide with one another, grinding down their surfaces and liberating more particles.

The best chance you have to see such particles — called meteoroids — as they wander the solar system is when one of them encounters Earth. As a particle plummets through our atmosphere, air friction produces a quick and fiery demise. The resulting streak of light is called a meteor. If Earth happens to run into the stream of dust particles recently left behind by a comet, we get a meteor shower. This month, the Orionid shower peaks October 21. With no Moon then in the sky, observers can expect to see up to 20 meteors per hour at the peak.

But there's another way to view interplanetary dust particles. Overall, they tend to congregate along the ecliptic, the plane of the solar system defined by the planets' orbits. The particles reach their highest density close to the Sun.

When sunlight strikes the particles, they reflect the light. This glow follows the ecliptic, which encompasses the zodiacal constellations, so it is known as the zodiacal light. If conditions are right, observers can see the glow. In its brightest parts, it glows brighter than the Milky Way.

JERRY SCHAAD

THE ZODIACAL LIGHT appears to sharp-eyed observers under a pitch-black sky on both spring evenings and autumn mornings.

October provides these prime conditions. This month, the ecliptic makes a steep angle to the eastern horizon before sunrise from northern latitudes. Shortly before twilight starts to paint the sky, about 2 hours before sunrise, scan above the eastern horizon for a faint pyramid of light. It may remind you of the approaching dawn (and has been called the "false dawn"), but the zodiacal light reaches a sharper peak.

To see the light, you will need clear, dry air and absolute darkness to the east. Even an intervening streetlight or the glow of a distant town will render it invisible. And moonlight certainly will drown it out, so the best times to look this year will be when the Moon's out of the morning sky in late September into early October and the last 10 days of October. The zodiacal light also can be glimpsed in the western sky after sunset, but the angle of the ecliptic favors observations in February and March.

Interplanetary dust shows up even less conspicuously as a glow called the "gegenschein." This glow lies exactly opposite the Sun in the sky and shows up best when this antisolar point lies near the zenith.

OCTOBER 06

S	M	T	W	T	F	S
1	2	3	4	5	●	7
8	9	10	11	12	◐	14
15	16	17	18	19	20	21
○	23	24	25	26	27	28
◑	30	31				

3	The Moon passes 3° south of Neptune, 3 A.M. EDT	
4	The Moon passes 0.5° south of Uranus, 8 P.M. EDT	
16	The Moon passes 2° north of Saturn, 10 A.M. EDT	
	Mercury is at greatest eastern elongation (25°), midnight EDT	
21	Orionid meteor shower peaks	
23	Mars is in conjunction with the Sun, 3 A.M. EDT	
24	The Moon passes 5° south of Jupiter, 4 A.M. EDT	
	The Moon passes 1.4° south of Mercury, 4 A.M. EDT	
25	The Moon passes 0.4° south of Antares, 10 A.M. EDT	
	Mercury passes 4° south of Jupiter, 6 P.M. EDT	
27	Venus is in superior conjunction, 2 P.M. EDT	
28	Mercury passes 4° south of Jupiter, 10 A.M. EDT	
30	The Moon passes 3° south of Neptune, 9 A.M. EST	

LEGEND	
	Events that can be viewed with the naked eye
	Events that can be viewed with binoculars
	Events that can be viewed with a telescope

THE AUTUMN SKY features the two brightest galaxies visible from north of the equator: M31 in Andromeda and M33 in Triangulum. *ASTRONOMY:* ROEN KELLY

This means the best time to look is around midnight and when interference from bright stars, planets, and the Milky Way is at a minimum. In these respects, October stands out. In 2006, prime time is within 5 days either side of the October 21/22 New Moon.

Learn the autumn sky

As the brilliant stars of the Summer Triangle descend in the west, they are replaced with a rather bland-looking region of sky. But don't let initial appearances deceive you. Hidden in the fall sky are gems equal to those of summer.

Cassiopeia, a group of five bright stars in the form of a "W" or "M" (depending on the time of night and time of year), lies directly overhead. To its east, Perseus rises high. Nestled between these two groups is the wonderful Double Cluster — NGC 869 and NGC 884 — a fantastic sight in binoculars or a low-power telescope.

Our view to the south of the Milky Way affords us a good look at the Local Group of galaxies. Due south of Cassiopeia lies the Andromeda Galaxy (M31), the largest member of the Local Group. A 4th-magnitude smudge of light, M31 passes nearly overhead on November evenings. Farther south lies the Pinwheel Galaxy (M33), a large, face-on spiral in Triangulum best seen in binoculars or a rich-field scope.

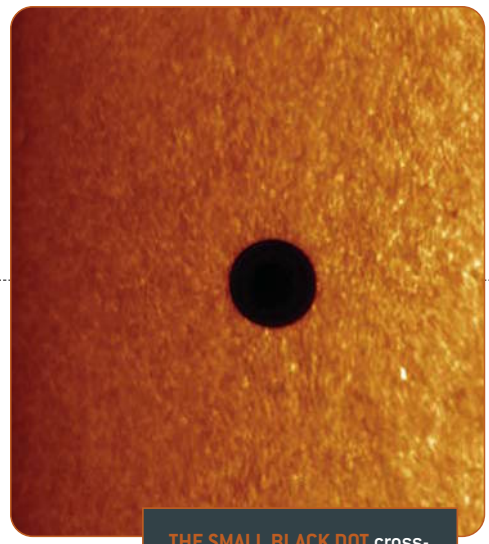
The Great Square of Pegasus passes just south of the zenith on autumn evenings. If you draw a line between the two stars on the square's right side and extend it southward, you'll find 1st-magnitude Fomalhaut, the lone bright star low in the south.

Well east of the square lies the Pleiades star cluster (M45) in Taurus, which reminds us winter lurks in the near future. By midnight in September, Taurus and Orion have cleared the horizon, and Gemini is rising in the northeast.

nov 2006

MERCURY transits the SUN

Mercury transits the Sun only 13 times a century, so don't miss the chance to view this rare event November 8. You'll need a small telescope and a good solar filter to see the planet's black disk crossing the Sun. Bring only your eyes to view November's other stellar event: a display of Leonid meteors that could rival the shows of a few years ago.



ROYAL SWEDISH ACADEMY OF SCIENCES

THE SMALL BLACK DOT crossing the Sun's face November 8 is Mercury. The planet will appear tiny — you'd have to place 180 Mercurys side by side to span the Sun's disk.

In June 2004, backyard astronomers witnessed the long-awaited Venus transit across the Sun's disk. The black ball of Venus clearly stood out against the blazing solar surface, even to the naked eye (properly protected from the Sun's brilliance, of course).

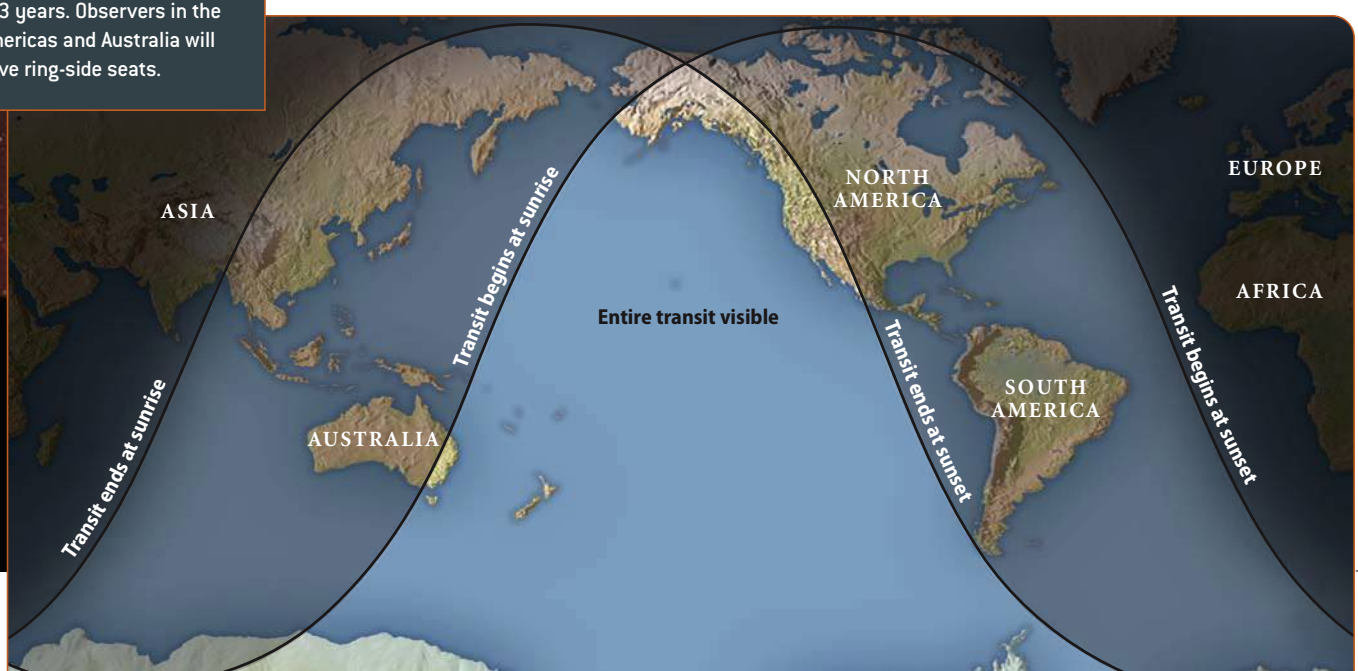
A more subtle transit of Mercury takes place November 8. During a period of 5 hours, the much smaller black disk of Mercury will move slowly across the Sun's countenance. You'll need a properly filtered telescope to see this event. Although not as rare as transits of Venus, transits of Mercury are uncommon, with only 13 occurring per century, on average. You'll have to wait 10 years for the next one.

For a transit to occur, a planet must pass between the Sun and Earth, a configuration known as inferior conjunction, at the same time the planet's inclined orbit crosses the ecliptic. Mercury's orbit crosses every year in May and November, so if it comes to inferior conjunction at those times, a transit occurs. In 1629, astronomer Johannes Kepler (1571–1630) first predicted a transit of Mercury using his newly formed laws of planetary motion. The transit occurred on schedule November 7, 1631, and French astronomer Pierre Gassendi (1592–1655) observed it.

On November 8, Mercury first nicks the Sun at 2:12 P.M. EST, a moment known as first contact. Two minutes later, Mercury's entire disk appears against the Sun's (second contact). For the next 4 hours and 54 minutes, the black disk moves gradually across the Sun. Mercury appears only 10" across — a far cry from the Sun's 30' diameter — just one-sixth as large as Venus during its transit. At 7:08 P.M. EST, Mercury encounters the eastern limb of the solar disk (third contact), and takes another 2 minutes to clear the Sun completely (fourth contact).

At least part of the transit will be visible across the United States. People in the Eastern time zone will see the first 2 hours of the transit until the Sun sets with Mercury

MERCURY TRANSITS THE SUN November 8 for the first time in 3 years. Observers in the Americas and Australia will have ring-side seats.



ASTRONOMY: ROEN KELLY

November 06

S	M	T	W	T	F	S
			1	2	3	4
●	6	7	8	9	10	11
◐	13	14	15	16	17	18
19	○	21	22	23	24	25
26	27	◑	29	30		

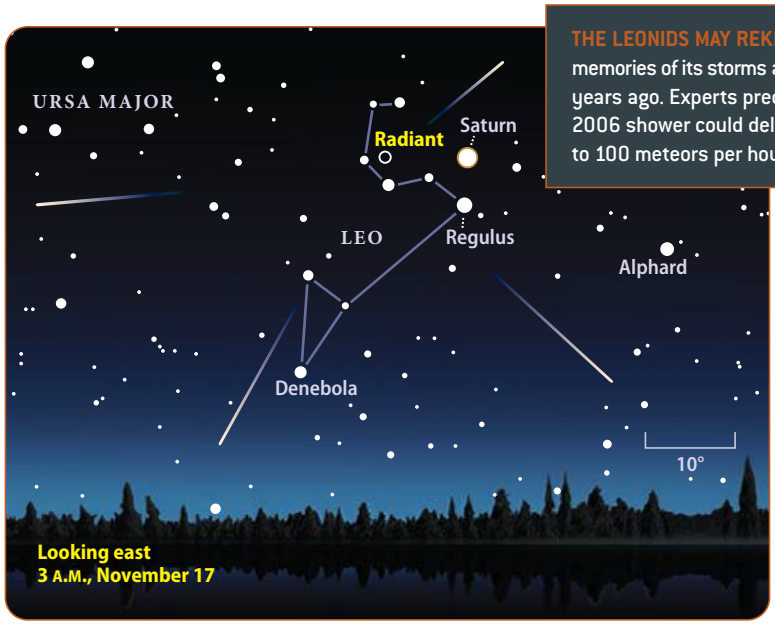
1	The Moon passes 0.5° south of Uranus, 3 A.M. EST	🔭
8	Mercury transits the Sun, 5 P.M. EST	🔭
12	The Moon passes 1.6° north of Saturn, 8 P.M. EST	👁 🔭
17	Leonid meteor shower peaks	👁
	The Moon passes 0.6° south of Spica, 10 P.M. EST	👁 🔭
19	The Moon passes 6° south of Mercury, 8 A.M. EST	👁 🔭
21	Jupiter is in conjunction with the Sun, 6 P.M. EST	
25	Mercury is at greatest western elongation (20°), 8 A.M. EST	👁 🔭
26	The Moon passes 3° south of Neptune, 4 P.M. EST	🔭
28	The Moon passes 0.3° south of Uranus, 10 A.M. EST	🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
	Events that can be viewed with a telescope

Meteor showers in 2006

Name	Peak	Moon's phase	Prospects
Quadrantids	Jan. 3	Waxing crescent	Good
Lyrids	April 22	Last Quarter	Poor
Eta Aquarids	May 5	First Quarter	Good
Perseids	Aug. 12	Waning gibbous	Poor
Orionids	Oct. 21	New Moon	Excellent
Leonids	Nov. 17	Waning crescent	Good
Geminids	Dec. 14	Waning crescent	Fair



ASTRONOMY: ROEN KELLY

THE LEONIDS MAY REKINDLE memories of its storms a few years ago. Experts predict the 2006 shower could deliver up to 100 meteors per hour.

nearly halfway across the disk. Midwesterners will see all but the last hour of the transit, while western observers can watch the entire event through fourth contact.

The next Mercury transit occurs May 9, 2016. The next transit of any kind will be June 6, 2012, when Venus transits the Sun for the second time in 8 years. There won't be another of those until 2117.

A strong Leonid shower

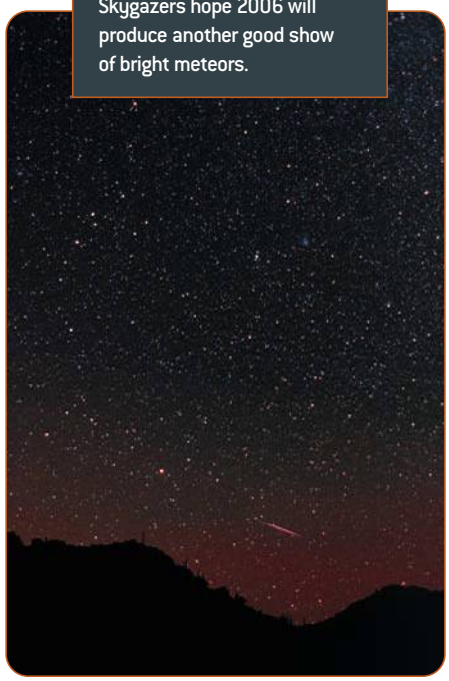
Meteor showers of varying intensity occur throughout 2006. Best viewing comes when the radiant, the region in space from which the meteors appear to stream, lies high in the sky, and the Moon is not in the sky at all.

These conditions are met for this year's Leonid meteor shower. Yet, the Leonids may have a bonus in store. Storm-level activity occurred in 1999, 2000, and 2001, when rates peaked at hundreds — if not thousands — of meteors per hour. This year probably won't approach those levels, but astronomers predict an outburst that could reach 100 meteors per hour.

In 2006, Earth passes through the debris trail left by the shower's parent comet, 55P/Tempel-Tuttle, in 1932. The short, sharp peak is expected in the early morning hours of November 19, with the best views coming from Europe and Africa. New Moon occurs November 20, so moonlight won't be a problem. The shower's traditional peak comes November 17, when rates may reach a few dozen meteors per hour.

The other meteor showers of 2006 probably won't equal the Leonids, but some will be worth a look. The best prospects, in addition to the Leonids, are for January's Quadrantids, May's Eta Aquarids, and October's Orionids. The traditional stalwart — August's Perseids — battles bright moonlight this year and won't perform to its usual level.

THE LEONID METEOR STORM of 2001 amazed observers in eastern Asia and Australia. Skygazers hope 2006 will produce another good show of bright meteors.



FRANK ZULLO

dec 2006

A trio of PLANETS

As the planets orbit the Sun, they constantly move in our sky. Occasionally, two or more planets will come together in what astronomers call a conjunction. The meeting of two bright planets can be impressive, but when three join together, the results are spectacular. Don't miss seeing Mercury, Mars, and Jupiter next to one another early this month.

JOE ORMAN

PLANETARY CONJUNCTIONS, like this one between brilliant Venus and fainter Mercury (to the right of the cactus), make beautiful photographic targets.

A dramatic early morning conjunction of three planets greets predawn risers in the first 2 weeks of December. Jupiter, Mercury, and Mars meet in the constellation Scorpius.

On December 1, Mercury is an easy target rising in the southeast an hour and a half before sunrise. Mercury's elongation from the Sun is decreasing, and as it does so, the planet meets Mars and Jupiter rising out of the twilight. Jupiter rises an hour before the Sun December 7 and shines at magnitude –1.7, while Mercury is at magnitude –0.8. Four degrees separate Jupiter and Mercury, while Mars, shining much fainter at magnitude 1.6, lies midway between the two bright objects.

On December 9, the three planets form a tiny triangle lying within a 1.5° circle. Watch them rise together in the southeast an hour before sunrise. Mars quickly will become hard to see against the brightening twilight.

On December 10, Jupiter and Mercury are closer, separated by 0.1°. While Mercury lies a mere 120 million miles away, Jupiter is nearly 5 times farther at 587 million miles. Yet, through a telescope, Jupiter spans 31", six times larger than Mercury's apparent diameter of 5".

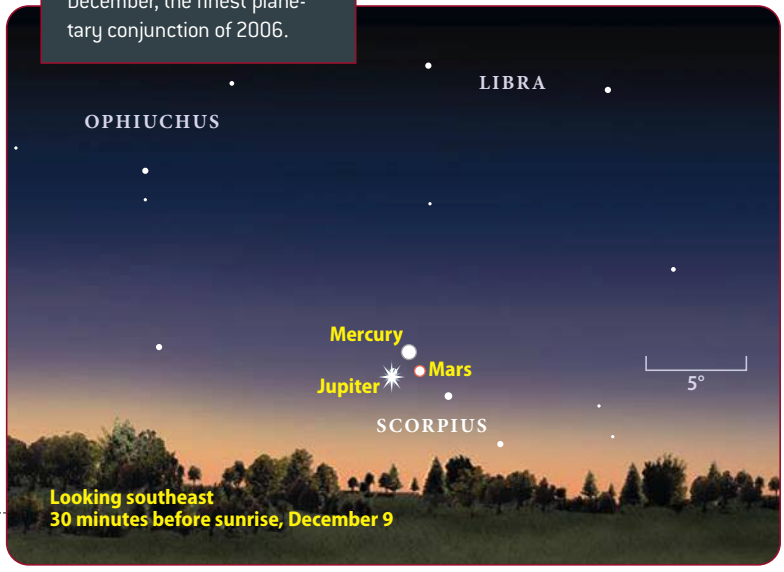
During the next few days, Mercury disappears while Jupiter rises earlier and climbs away from Mars, whose own climb out of the twilight is much slower. A thin crescent Moon arrives at a location 6° south of Jupiter December 18. Mars lies 3.5° east of Jupiter. Be careful not to confuse Mars with its rival, Antares. Scorpius' brightest star lies 4.5° south of Mars December 18.

Target: Perseus

Late autumn and early winter provide the best views of the constellation Perseus the Hero. Located in the heart of the Milky Way, Perseus features plenty of open star clusters and nebulae splayed against a rich stellar backdrop.

One Perseus star ranks among the most famous in the sky. Algol normally shines at magnitude 2.1. Yet every 2 days, 20 hours, and 49 minutes, it dims by 70 percent to magnitude 3.4. This darkening arises when a smaller, fainter star orbiting Algol passes in front of it,

MERCURY JOINS MARS AND JUPITER before dawn in early December, the finest planetary conjunction of 2006.



ASTRONOMY: ROEN KELLY

DECEMBER 06

S	M	T	W	T	F	S
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3	●	5	6	7	8	9
10	11	◐	13	14	15	16
17	18	19	○	21	22	23
24	25	26	◑	28	29	30
31						

9	Mercury passes 1.0° north of Mars, 3 P.M. EST	👁 🔭
10	The Moon passes 1.2° north of Saturn, 6 A.M. EST	👁 🔭
	Mercury passes 0.1° north of Jupiter, 11 A.M. EST	👁 🔭 🔭
11	Mars passes 0.8° south of Jupiter, 7 P.M. EST	👁 🔭
14	Mercury passes 5° north of Antares, 3 A.M. EST	👁 🔭
	Geminid meteor shower peaks	👁
15	The Moon passes 0.8° south of Spica, 6 A.M. EST	👁 🔭 🔭
18	Pluto is in conjunction with the Sun, 10 A.M. EST	
	The Moon passes 6° south of Jupiter, 4 P.M. EST	👁 🔭
	Mars passes 4° north of Antares, 10 P.M. EST	👁 🔭
	The Moon passes 0.4° south of Antares, 11 P.M. EST	👁 🔭 🔭
	The Moon passes 5° south of Mars, 11 P.M. EST	👁 🔭
21	Solstice (northern winter/southern summer begins), 7 P.M. EST	👁
23	The Moon passes 3° south of Neptune, 10 P.M. EST	🔭
25	The Moon passes 0.08° north of Uranus, 4 P.M. EST	🔭 🔭

LEGEND

👁	Events that can be viewed with the naked eye
🔭	Events that can be viewed with binoculars
🔭	Events that can be viewed with a telescope

GEORGE GREANEY

THE CALIFORNIA NEBULA bears some resemblance to its namesake state. The emission nebula is just one of several spectacular deep-sky objects adorning Perseus.

blocking much of the brighter star's light. Each eclipse lasts about 10 hours.

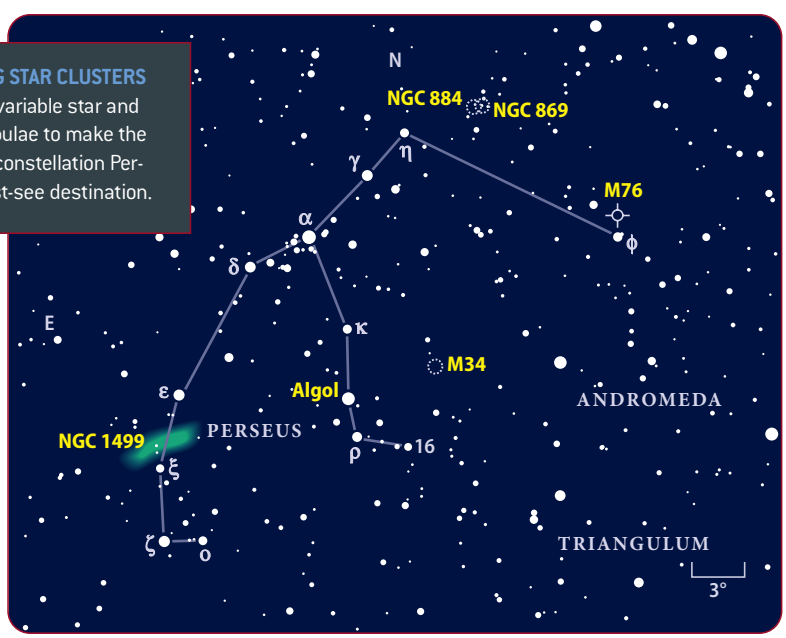
Just 5° west-northwest of Algol lies the 5th-magnitude open cluster M34. Visible to the naked eye from a dark site, it stands out in a small telescope, which shows 10 stars brighter than 9th magnitude. A 6-inch scope will show about 40 members shining across 1,500 light-years of space.

You can double your observing pleasure by looking in northern Perseus, near the constellation's border with Cassiopeia. There, you will find the famous Double Cluster (NGC 869 and NGC 884). This pair of colorful star clusters ranks among the prettiest sights in the sky. Use an eyepiece that delivers about a 1° field to get the best impression of this splendid region. NGC 869 (the western component) appears the richer of the two clusters, containing some 200 stars. Although it appears less concentrated, NGC 884 contains more bright stars.

In the far western corner of Perseus lies the Little Dumbbell Nebula (M76). This planetary nebula glows at magnitude 10.1, giving it the distinction of being the faintest object in Charles Messier's catalog of 107 deep-sky objects. Nevertheless, it appears fairly bright through a small telescope and reveals an elongated disk that holds up well to high magnification. An 8-inch scope reveals the two lobes that give the nebula its name.

Our final stop in Perseus has a much larger glow. The California Nebula (NGC 1499) spans more than 2°, four times the Full Moon's diameter. This emission nebula represents a region where stars are being born. The ultraviolet light from the hot newborn suns excites the surrounding gas, causing it to glow. A 4-inch scope should let you make out the nebula's entire size and shape.

GLITTERING STAR CLUSTERS join with a variable star and several nebulae to make the Milky Way constellation Perseus a must-see destination.



ASTRONOMY: ROEN KELLY

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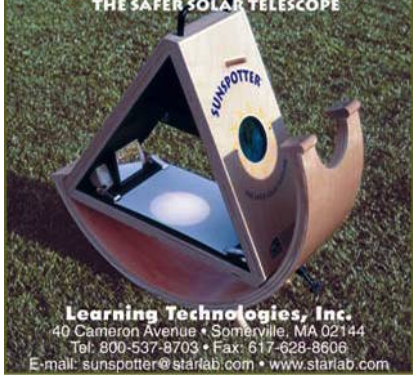

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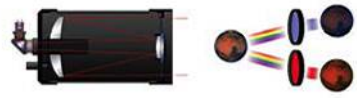

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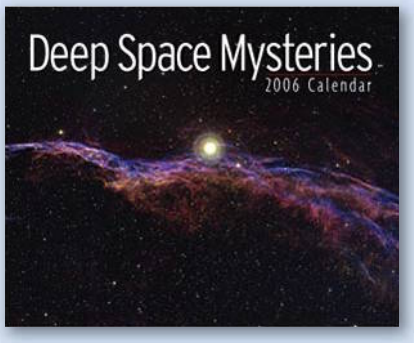

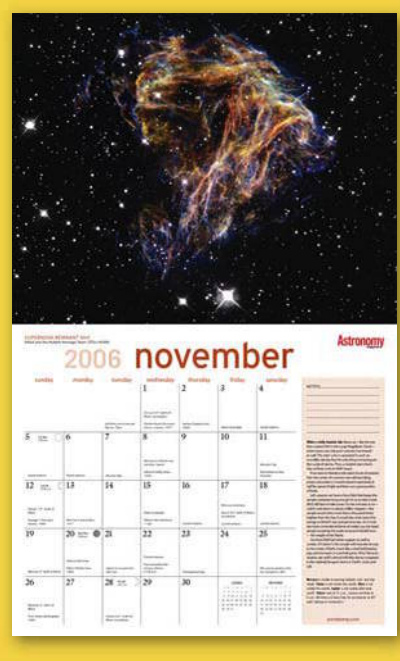

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MICHAEL E. BAKICH is an associate editor of *Astronomy* magazine.

ADAM BLOCK/NOAO/AURA/NSF

A DARK OBJECT like the Horsehead Nebula (B33, center) is as interesting to observe as a bright object like the Flame Nebula (NGC 2024, left).

deep sky guide 2006

2006

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TELESCOPIC OBSERVING

DON'T MISS THIS YEAR'S DEEP-SKY OBJECTS

Planets are only some of the cool celestial objects in the 2006 night sky. Once you move out of our solar system, bright star clusters, nebulae, and galaxies exist in dazzling profusion. If you own a small telescope, try your hand at double-star observing. If you have a large telescope, tackle the "Big-scope challenges" for each month.

BEST OBSERVING VS. BRIGHT MOON NIGHTS | BEST: JAN 1–4, 26–31 | WORST: JAN 10–18

THE ORION NEBULA (M42) is a cosmic nursery 1 light-year across. Here, stars are forming from a vast cloud of gas and dust. JOHN CHUMACK

jan

HUNTING IN ORION

In January, one constellation — Orion — offers many great reasons to bundle up and observe.

The winter's best deep-sky object is the Orion Nebula (M42). Through a 3-inch scope, you can see gas clouds in shades of gray, and the Trapezium — four stars recently formed from the nebula's material — is easy to spot. A 12-inch scope further divides two of the four stars into pairs, for a total of six.

Be dynamic in your approach to the Orion Nebula. Move your telescope around a bit to study the wispy tendrils of M42's outer regions better. Change the magnification, and you'll notice something new each time — foreground stars, high-contrast regions, and more.

Just north of M42 is M43 (NGC 1982). At its heart is 7th-magnitude NU Orionis. Note the dark cloud that overlays the bright gas on M43's eastern side.

For more bright nebulae, move ½° north of M42 to NGC 1973–5–7, a complex known as the Running Man Nebula. The 5th-magnitude stars 42 and 45 Orionis shine within the nebulosity. This region would be more observed were it not for the proximity of the Orion Nebula.

The brilliant glare of Zeta (ζ) Orionis, the bottom star in Orion's "belt," normally hides two nebulae of different appearance. The Flame Nebula (NGC 2024) is an emission nebula, and the Horsehead Nebula (B33) is a dark nebula.

OBSERVING TIP

Focus when you first look through the eyepiece and often thereafter. Don't be satisfied with the first focus setting — keep adjusting as needed during the course of your observation.

BIG SCOPE CHALLENGE

THE HORSEHEAD NEBULA

Once considered the "ultimate" observing test, the Horsehead isn't impossible to locate if you heed these tips: 1) Use a big scope. Observers have seen the Horsehead in 5-inch scopes, but not easily. 2) Let your eyes dark adapt. 3) Increase the magnification to position the bright star Alnitak (Zeta Orionis) outside the field of view. A photograph of this area will serve you better than a star chart. 4) When you do approach the eyepiece, begin by searching for the bright nebula IC 434. If you can't see it steadily, you won't see the Horsehead. 5) If you're serious about observing the Horsehead, do yourself a favor — purchase or borrow a Hydrogen-beta filter.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Epsilon (ε) Monocerotis	4.5, 6.5	13.4"
Beta (β) Monocerotis	4.7, 5.2	7.3"
Alpha (α) Geminorum (Castor)	1.9, 2.9	2.2"

BEST OBSERVING VS. BRIGHT MOON NIGHTS | BEST: FEB 1–3, 23–28 | WORST: FEB 9–17

THE TAU (τ) CANIS MAJORIS CLUSTER (NGC 2362) resembles diamonds strewn across a small region of sky. GEORGE GREANEY

feb

DOG NIGHTS OF WINTER

The dog days of summer refer both to the stifling heat of August and to the first morning-sky appearance of the Dog Star, Sirius. To the ancient Egyptians, the first time they could see "the star of Osiris" before sunrise also marked the beginning of the Nile River's annual flooding.

When you're hunting celestial quarry in Canis Major, it's a good bet open clusters are what you're after. Sirius (Alpha Canis Majoris), the night sky's brightest star, provides a guide to M41 (NGC 2287), an open cluster 4° to its south. This cluster is visible to the naked eye, but it really shows off at low power in 6-inch or larger telescopes. The brightest member is a 7th-magnitude orange star, which contrasts nicely with the dozens of fainter bluish-white stars in the field of view.

For a real treat, seek out NGC 2362, the brightest open cluster in Canis Major. It's called the Tau (τ) Canis Majoris cluster because this group of more than 50 stars surrounds that magnitude 4.4 star.

All the stars except for Tau, however, are faint, so what you'll see is one luminary surrounded by a powdery field. Too low a magnification will allow Tau to overwhelm the cluster, so pump up the power, and you'll see a lot more stars.

OBSERVING TIP

If your target object is faint, tap the telescope tube lightly — the motion often helps bring the object into view. This tip also works when looking for subtle details in large objects, like the spiral arms of galaxies.

BIG SCOPE CHALLENGE

PROCYON B

Many observers have seen Sirius B. Splitting Sirius offers a challenge because of the nearly 10-magnitude brightness difference between the two stars. Procyon (Alpha Canis Minoris) is also a double star — its components (A and B) shine at magnitudes 0.34 and 10.7. But because Procyon is one-fifth as bright as Sirius, Procyon B is easier to see. If you plan to observe it, do so quickly. The current separation of 3" is closing, and A and B won't be this wide again until 2012.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Kappa (κ) Puppis	4.5, 4.7	9.9"
Zeta Cancri	5.6, 6.0	5.9"
Regulus (Alpha Leonis)	1.4, 7.7	177.0"

YOU'LL SEARCH A LONG TIME to find a better example of a spiral galaxy than NGC 2903 in Leo.
GEORGE HICKEY/ADAM BLOCK/NOAO/AURA/NSF

mar

THE LION ROARS

Poke a hole in the Big Dipper's "bowl," let all the water run out, and you'll hear a mighty roar as the water falls on the back of Leo the Lion, springtime's first great constellation. Don't point your telescope toward Leo for star clusters — you can observe several nice ones in neighboring Cancer — but for galaxies. So get to a dark site, buy or borrow a big scope, put away your filters, and adjust your mindset for "faint fuzzies."

Look midway between Regulus (Alpha Leonis) and Theta (θ) Leonis to find the Leo group: M95, M96, and M105. Magnitude 9.2 M96 is the brightest, followed by M105 at magnitude 9.3, and M95, still a respectable magnitude 9.7. A 4-inch scope will show these galaxies, but you'll want at least a 10-inch to compare their features.

Move east 9°, and you'll find three more bright galaxies known as the Leo Triplet. M66 shines at 9th magnitude and is twice as long (8.7') as it is wide (4.4'). North of M66, and visible in the same low-power view, is M65, an elongated galaxy (10' by 3.3') that shines at magnitude 9.3. NGC 3628 completes the trio.

One object you shouldn't miss is NGC 2903, the brightest galaxy in Leo. Find this treasure 1.5° south of Lambda (λ) Leonis. Magnitude 8.9 NGC 2903 measures 13' by 6.6'.

OBSERVING TIP

Use high magnification if conditions allow. High powers often will reveal details a low-power view won't show. Remember, as you increase the magnification, you darken the background. Use this to your advantage.

BIG SCOPE CHALLENGE

LEO I

This month, look for the dwarf spheroidal galaxy Leo I. Relatively few observers have seen this object, a fact that sounds strange given its relatively bright visual magnitude of 9.8.

The difficulty in spotting this galaxy comes from its proximity to Regulus (Alpha Leonis). Leo I lies a mere 12' from that brilliant star, so some of Regulus' light intrudes into a telescopic field of view centered on the galaxy. Combine a night with great seeing, a dark site, and a time when Regulus is high in the sky, and you should have no trouble finding this well-hidden treasure.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Algieba (Gamma [γ] Leonis)	2.2, 3.5	4.4"
Porrima (Gamma Virginis)	3.5, 3.5	3.6"
Mizar (Zeta Ursae Majoris)	2.3, 4.0, 4.0	14.4", 700.0"

NGC 3726 in Ursa Major is a worthy target for a large telescope.
GEORGE HICKEY/ADAM BLOCK/NOAO/AURA/NSF

apr

BEARS AND SPIRALS

The region in and around Ursa Major the Great Bear contains some of the sky's great spiral galaxies — M81 and M101 in Ursa Major, and M51 in Canes Venatici. Venture past this formidable trio, and a second tier of superb spirals awaits you.

Start with NGC 2841, a magnitude 9.3 galaxy 8' by 4'. You'll need a 16-inch scope to trace out the arms, which are as tightly wound as you'll see in a spiral galaxy.

Next, find NGC 3079. You won't see much detail, but this galaxy is noteworthy because of the active star formation occurring in its nucleus. NGC 3079 measures 6' by 2', and its long axis orients nearly north-south.

South and a bit west of Chi (χ) Ursae Majoris lies NGC 3726, a magnitude 10.4 spiral that measures 6' by 4.5'. Through a 12-inch telescope, you'll notice this galaxy's core is somewhat mottled and roughly 3 times as long as it is wide. Its arms are peppered with bright areas.

Spiral galaxy M108 is relatively bright, but you won't be able to pick out its arms. In 8-inch and smaller scopes, this galaxy looks like a ghostly lens floating in the field of view. Larger scopes reveal details like its bright, elongated core and unevenly illuminated outer regions. M108 shines at 10th magnitude and measures 8.3' by 2.5'.

OBSERVING TIP

If you're observing spiral galaxies, both a large telescope and a dark sky are essential. Pay particular attention to the central condensation, subtle brightness variations, overall shape, and the extent of the spiral arms.

DOUBLE STARS NOT TO MISS!

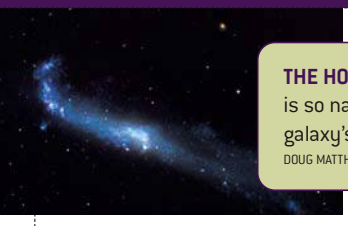
STAR	MAGNITUDES	SEPARATION
Epsilon Monocerotis	4.5, 6.5	13.4"
Beta Monocerotis	4.7, 5.2	7.3"
Castor (Alpha Geminorum)	1.9, 2.9	2.2"

BIG SCOPE CHALLENGE

POLARISSIMA BOREALIS (NGC 3172)

If you're like many amateur astronomers, you enjoy observing objects that are the farthest and the faintest. One galaxy, NGC 3172, is the NGC object that lies closest to the North Celestial Pole. Because of its proximity — less than 1° from that most northerly declination point — it received the name Polarissima Borealis.

The galaxy glows feebly at magnitude 13.6 and is elongated, measuring roughly 1' by 0.7'. Seeing NGC 3172 through a 12-inch telescope takes effort.



THE HOCKEY STICK (NGC 4656) is so named for the offset on the galaxy's northeastern edge.
DOUG MATTHEWS/ADAM BLOCK/NOAO/AURA/NSF

may

REALM OF THE GALAXIES

Virgo, Coma Berenices, and Canes Venatici contain the largest number of bright galaxies in the sky.

Before you tour this region, keep several tips in mind. First, print a star chart matching the orientation of your eyepiece. Second, be certain of your identifications. At times, half a dozen or more galaxies will crowd into your field of view. Third, when galaxies are your targets, use the biggest telescope you can. Fourth, although you'll observe on moonless nights, you may notice this area appears brighter than expected. If so, you're seeing the gegenschein, or counterglow, caused by small interplanetary particles reflecting sunlight. At a dark site, the gegenschein can appear bright. To offset this glow, increase the magnification, which will darken the sky in your field of view.

Three galaxies in Canes Venatici will delight you. NGC 4244, a fabulous edge-on spiral, looks 10 times as long as it is wide. NGC 4631, often called the Whale, glows at magnitude 9 and shows tremendous detail in 12-inch and larger scopes. Its 12th-magnitude companion, NGC 4627, will appear oval. It measures 2.7' by 2'. Next, find the Hockey Stick (NGC 4656), just southeast of NGC 4631. The bright northeastern edge of this 10th-magnitude galaxy appears offset, forming the stick's blade.

I'll leave you with a list of favorites — all brighter than 10th magnitude — that really will jump out of the background: In Virgo, look for M49, M58, M60, M61, M84, M86, M87, M90, and M104. And you'll find more bright galaxies in neighboring Coma Berenices: M53, M64, M85, M88, and M100.

OBSERVING TIP

When you're observing galaxies, especially in rich areas such as the constellations Coma Berenices and Virgo, check the field of view carefully. Your telescope may reveal galaxies not on your star map.

BIG SCOPE CHALLENGE

THE MICE (NGC 4676A/4676B)

Colliding galaxies called the Mice, because of the "tail" that extends from each galaxy, lie in Coma Berenices, 300 million light-years away. The northern "mouse" (NGC 4676A) has a thin, bright tail and glows at magnitude 13.8. NGC 4676B has a dimmer, broad tail and, at magnitude 14, appears slightly fainter overall. View the Mice through a big telescope — you'll need at least 20 inches of aperture.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Graffias (Beta Scorpii)	2.6, 4.9	13.6"
Kappa Herculis	5.3, 6.5	28.0"
Nu (ν) Scorpii	4.3, 6.4	41.0"

NEAR THE SCORPION'S STINGER lies M7, a fabulous naked-eye open cluster.
ALLAN COOK/ADAM BLOCK/NOAO/AURA/NSF

jun

NIGHT OF THE SCORPION

And now for something completely different. The last 2 months were perfect for galaxies. However, with the summer Milky Way coming into view, this is the time to observe star clusters and nebulae.

Nestled within the curve of the Scorpion's "tail" and about 4° west of the "stinger," you'll find the Bug Nebula (NGC 6302). Classified as a planetary nebula, the Bug appears elongated, with dimensions of 83" by 24". An easily seen stellar core lies slightly east of its center. If you use a 12-inch or larger telescope and a magnification of about 300x, you'll see both lobes of gas that give this small object its shape.

Located 2° northeast of the Bug Nebula, the Cat's Paw Nebula (NGC 6334) consists of a five-part complex spanning 30'. Unfortunately, a small scope won't reveal much, but a 12-inch or larger scope — plus a nebula filter — will have you swimming in nebulosity.

M6 (NGC 6405) and M7 (NGC 6475) are famous open clusters near the scorpion's stinger. Both clusters are visible to the naked eye, and dozens of bright stars fill the field of view through binoculars or a small telescope. Less well-known — but brighter than either of these (at magnitude 2.6) — is NGC 6231, which lies just north of Zeta Scorpii. A 3-inch telescope shows several dozen stars. Increase your aperture to 8 inches, and more than 100 stars will come into view. This open cluster measures nearly ½° across.

OBSERVING TIP

To help dark adaption, wear an eyepatch over your observing eye before and during setup. Move the patch to your non-observing eye when you observe. This will allow you to keep both eyes open, relieving the strain on your eye muscles and extending your session.

BIG SCOPE CHALLENGE

ANTARES B

If you see a scope pointing in the vicinity of Antares, you may assume a globular cluster is the target. But Antares itself offers a challenge. Some observers have resolved Antares' components with 4-inch telescopes. Antares B lies 3" from the primary and shines at magnitude 6.5. Because it contrasts with the brilliant reddish primary, Antares B appears green. Some observers report success using either a light blue or an OIII filter to subdue some of Antares' light.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Ras Algethi (Alpha Herculis)	3.5, 5.4	4.7"
36 Ophiuchi	5.1, 5.1	4.4"
90 Herculis	5.2, 8.5	1.6"

THE GHOSTLY SHELL of planetary nebula Abell 39 reveals itself only through large telescopes. ADAM BLOCK/NOAO/AURA/NSF

jul

OBSERVING TIP

If your scope is large and your sky steady, crank up the magnification and pick out individual red supergiants that make up globular clusters. Omega Centauri (NGC 5139) is a good place to start.

ROUND, BRIGHT, AND BEAUTIFUL

Many owners of 8- to 12-inch telescopes say their best deep-sky views come when they observe globular clusters. I agree. Globular clusters are so named because they're round. But don't think they all look the same.

Of the Milky Way's roughly 150 known globulars, more than a third are clustered in three constellations: Ophiuchus, Scorpius, and Sagittarius.

Start in Ophiuchus with its seven Messier globulars. I normally don't suggest taking a quick look at an object before jumping to the next one, but in this case it's worthwhile because it will show you that all globulars are not created equal. Start with M14, swing westward to M10, then up to M12, south to M107, a bit farther south to M19, even farther south to M62, and finally northeast to M9. Spend no more than a minute on each the first time around.

In Scorpius, contrast M4 with M80, a globular 4° to its northwest and 7 times more distant. M80 is more compact, and its stars are more difficult to resolve. Through a 12-inch scope, you'll count about 50 stars in M80.

Now head to Sagittarius, where another gaggle of great globulars gathers. Seven Messier globulars — M22, M28, M54, M55, M69, M70, and M75 — populate this constellation. Each object warrants repeated views, but M22 stands out as one of the sky's finest globulars.

BIG SCOPE CHALLENGE

ABELL 39

All planetary nebulae in the Abell catalog are difficult targets, but few are as rewarding to see as Abell 39 in Hercules. This magnitude 13.7 planetary spans 3′ and is perfectly round. Be sure to use at least a 16-inch scope, 100x, and an OIII filter. For a greater challenge, try to spot Abell 39's magnitude 15.7 central star.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Epsilon Lyrae	5.0, 6.1; 5.2, 5.5	2.6"; 2.3"
Theta Serpentis	4.5, 5.4	22.3"
Albireo (Beta Cygni)	3.1, 5.1	34.4"

ONE OF THE SKY'S most observed planetary nebulae is the Ring Nebula (M57). But can you see its central star? ADAM BLOCK/NOAO/AURA/NSF

aug

OBSERVING TIP

Avoid eye fatigue by taking 1-minute breaks every 20 minutes. During the breaks, lightly cup your eyes with your palms. Another technique is to look away from the eyepiece and roll your eyes up and down and side to side for 20 seconds. Then relax, eyes closed, for 30 more seconds.

THREE FOR THE PRICE OF ONE

Three constellations — Lyra, Cygnus, and Aquila — lend bright stars to the Summer Triangle, which straddles the Milky Way.

Start 3° east of Deneb (Alpha Cygni) to find the North America Nebula (NGC 7000). Visible to the naked eye from a dark site, the North America shows up best in a wide-field telescopic view through a nebula filter.

Move 1° back toward Deneb to find the Pelican Nebula (IC 5067–70). The Pelican is tougher to observe than the North America Nebula. Use an 8-inch scope, a nebula filter, and an eyepiece that yields a wide field of view.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
49 Cygni	5.7, 7.8	2.7"
Gamma Delphini	4.7, 5.2	9.6"
61 Cygni	1.9, 2.9	28.0"

If you have a 16-inch or larger Dobsonian-mounted telescope, point it at the Veil Nebula (NGC 6960, NGC 6979, and NGC 6992–5.). Install a wide-field eyepiece and an OIII filter. Find part of the Veil, and then move your scope to follow the extent of this wondrous object. You'll be surprised how large and intricate the Veil appears. If your scope has a driven mount, disengage the motors before freewheeling.

In addition to bright nebulae, lots of dark nebulae populate this region. Look 1° west of Gamma Aquilae to find two dark nebulae — Barnard 142 and 143 — that form a figure known as Barnard's E. A wide-field view is best, but you won't need a filter.

BIG SCOPE CHALLENGE

M57'S CENTRAL STAR

Seeing the Ring Nebula's central star is a worthy goal if you own a 16-inch or larger scope. Wait until the Ring stands at least 60° high in the sky, and use at least 300x. Remember that you're trying to emphasize the contrast between the star and the nebulosity within the ring. Excellent seeing is crucial. If you can't see the magnitude 14.7 star just off the Ring's northwestern edge, you won't see the central star.

THIS SKETCH OF PEASE 1 within globular cluster M15 accurately portrays the view through a 14-inch or larger telescope. DANIEL RESTEMEIER

sep

THE BEAUTY OF STAR DEATH

When a Sun-like star exhausts its supply of energy-generating hydrogen and helium, it expels its outermost layers. This gas shell glows for tens of thousands of years until it moves out of range of the radiation from the white dwarf remnant at its center. We call such expanding gas clouds planetary nebulae because 19th-century astronomer John Herschel likened their small-telescope appearance to that of the outer planets Uranus and Neptune.

September is a great time to observe planetary nebulae. But be warned: Most are small and faint. To see detail — including color — use a big scope.

Start high in the south with NGC 6781 in Aquila. This planetary is 1.7' in diameter with a 40" central hole.

Move southeastward to Aquarius to find the greenish-blue Saturn Nebula (NGC 7009). At 45" by 25", NGC 7009 responds well to high magnification.

Next, move to Cygnus for the Blinking Planetary (NGC 6826). To get the full effect of this object, I recommend a small scope. Stare at the object, and you'll see the 25"-diameter nebula. Avert your gaze a couple of nebula diameters to any side, and you'll see the central star. (In an 8-inch or larger scope, the central star is visible continuously.)

An object that looks different through different apertures is the Blue Snowball (NGC 7662). A 4-inch scope shows it as a small, sky-blue disk. With an 8-inch scope, you'll see irregularities. At 200x through a 12-inch scope, the 32" by 28" nebula has a central hole surrounding a 13th-magnitude star.

OBSERVING TIP

To identify planetary nebulae too small to show a disk, "blink" the field of view by moving an OIII filter held securely between your eye and the eyepiece back and forth. Any "star" retaining its brightness when viewed through the filter is a planetary.

BIG SCOPE CHALLENGE

PEASE 1

Planetary nebulae are fun to observe, although some are faint and hard to see. The most difficult are the few planetaries within globular clusters. One of these, Pease 1, lies within M15 in Pegasus. Pease 1 has been observed through an 11-inch scope, but you'll find it easier to see in a bigger scope. Blinking with an OIII filter will help because you'll see only the core of M15 and the faint glow of Pease 1 through the filter.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Xi (ξ) Cephei	4.4, 6.5	7.7"
Delta (δ) Cephei	3.9, 6.3	41.0"
Iota (ι) Cassiopeiae	4.6, 6.9, 8.4	2.5", 7.2"

DISTINGUISHING ALL FIVE GALAXIES in Stephan's Quintet is a good test of both the observer and sky quality. ADAM BLOCK/NOAO/AURA/NSF

oct

JEWELS OF THE NORTH

In the Northern Hemisphere's autumn, the upper tier of constellations — specifically Cassiopeia, Cepheus, and Perseus — offers observers a wide range of objects.

Start at Cassiopeia's western edge and move eastward. Observe M52, the Owl Cluster (NGC 457), and Stock 2. A 10-inch scope will pull in more than 100 stars from each. Use high magnification when observing M52 (13' in diameter) and the Owl (12' in diameter) but a wide-field eyepiece for 1°-wide Stock 2.

If you have access to a 12-inch or larger scope, don't miss the Bubble Nebula (NGC 7635). With a large aperture and a nebula filter, the Bubble appears like a ring structure that surrounds an 8th-magnitude star. Don't expect to see the whole ring.

In Cepheus, start with NGC 7380, a 12'-wide, 7.2-magnitude open cluster. Through a 12-inch or larger telescope, as many as 75 stars pop into view. Add a nebula filter to dim the cluster's stars, and you might see the faint emission nebula Sharpless 2–142, which surrounds NGC 7380.

NGC 40, a wonderful planetary nebula, allows you to use a full complement of eyepieces. The nebula glows at magnitude 12.4; and 8-inch or larger scopes reveal the magnitude 11.5 central star. Larger scopes and higher magnifications reveal NGC 40's mottled, slightly uneven appearance.

If you have a 12-inch scope, head to Perseus to find Abell 426 — the Perseus I galaxy cluster. NGC 1275, which shines at magnitude 11.6, and NGC 1272 are the luminaries of this cluster. Other bright galaxies include NGC 1250 (magnitude 14.2), NGC 1273 (magnitude 12.9), NGC 1282 (magnitude 12.9), and NGC 1294 (magnitude 13.1).

OBSERVING TIP

Faint open clusters often look better with small scopes. A large scope, because it collects lots of light, may reveal too many background stars, making the cluster's boundary difficult to see.

BIG SCOPE CHALLENGE

STEPHAN'S QUINTET

Simply seeing Stephan's Quintet (NGC 7317, NGC 7318A, NGC 7318B, NGC 7319, and NGC 7320) is not a challenge. You can glimpse the brightest, NGC 7320, in an 8-inch scope. Differentiating the galaxies' sizes, shapes (3 are spirals, 2 are ellipticals), and brightnesses, however, requires at least a 16-inch telescope.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
65 Piscium	6.3, 6.3	4.4"
Zeta Piscium	5.6, 6.5	23.0"
Gamma Arietis	4.8, 4.8	7.8"

BRIGHT NEBULAE like IC 410 show lots of detail through 12-inch and larger telescopes. MARK HANSON

nov

THE CHARIOT'S PATH

Auriga the Charioteer frames part of the winter Milky Way that's alive with celestial objects ranging from naked-eye star clusters to faint nebulae. Its position — nearly overhead at year's end — is perfect for long observing sessions.

Start with the three Messier open clusters in Auriga: M36 (NGC 1960), M37 (NGC 2099), and M38 (NGC 1912). Of these, M36 is the poorest, with only 50 stars visible through even a large telescope. M38 more than doubles the star count of M36, and its brightest stars form a crooked "X." M37 moves us into a new observing dimension — so many stars can be counted that M37 has been compared to weak globular clusters. One of its members, a magnitude 9.2 red star best viewed at low magnification, shines conspicuously near the center.

Two Index Catalogue (IC) objects worthy of your attention in Auriga are IC 405 and IC 410. IC 405, the Flaming Star Nebula, contains reflection and emission nebulae and surrounds the variable star AE Aurigae. Even through a large scope, IC 405 shows only a fanlike protrusion emanating from AE Aurigae.

IC 410, 1.5° southeast of IC 405, presents a better target. One-half degree across, IC 410 displays both bright and dark areas. If you are using a 12-inch or larger telescope, a nebula filter really helps to bring out the contrast differences visible among portions of IC 410.

OBSERVING TIP

Color filters you insert into an eyepiece are of no use in deep-sky observing. Furthermore, nebula filters are of no use on galaxies or star clusters. Use nebula filters on the objects for which they're named.

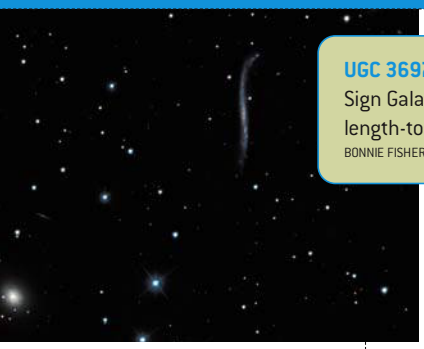
BIG SCOPE CHALLENGE

GYULBUDAGHIAN'S NEBULA

Some amateurs make a fuss about this object (pronounced gyool-boo-DAH-ghee-an) simply because of its name. Its variability — which seems to be random — transforms it from a challenge object in a 20-inch scope to a relatively easy catch in a 10-inch at irregular intervals. Normally, you'll see the star PV Cephei at the apex of a faint, fan-shape nebula that stretches northward.

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Gamma Andromedae	2.3, 5.5	9.8"
Iota Trianguli	5.3, 6.9	3.9"
Theta Eridani	3.4, 4.5,	4.5"



UGC 3697, otherwise known as the Integral Sign Galaxy, has an incredible 10-to-1 length-to-width ratio. BONNIE FISHER AND MIKE SHADE/ADAM BLOCK/NOAO/AURA/NSF

dec

TAMING THE BULL

Ask most amateurs about objects in Taurus the Bull, and you'll probably get a list of three: the Pleiades (M45), the Hyades, and the Crab Nebula (M1). But there's much more, especially if you have access to a large telescope.

First, though, let's examine the Pleiades more closely. Point a 6-inch or larger telescope at the star Merope to observe NGC 1435, the Merope Nebula. The test here is to observe a faint nebula surrounding a bright star, which makes the nebula hard to see due to glare. Seeing the Merope Nebula is possible only on the best nights.

The Crab Nebula, a supernova remnant, can be viewed even from urban settings with a small telescope. To study this object's visible details, however, point a 12-inch or larger scope its way. The filaments, so easily seen in large-telescope images of the Crab, are elusive and will require averted vision. Try to see an "S" shape in the Crab's brightest parts.

A nice planetary — NGC 1514 — sits at Taurus' northern edge. Small telescopes show a featureless glow, but a 12-inch scope reveals an irregular, nebulous ring about 2' across surrounding a magnitude 9.4 star, but not the star that created the planetary nebula. The progenitor is now a white dwarf star, an invisible companion to the bright star at NGC 1514's center. A

DOUBLE STARS NOT TO MISS!

STAR	MAGNITUDES	SEPARATION
Polaris (Alpha Ursae Minoris)	2.0, 9.0	18.4"
Rigel (Beta Orionis)	0.1, 6.8	9.5"
Mintaka (Delta Orionis)	2.2, 6.3	52.6"

OBSERVING TIP

Constantly ask yourself questions about the objects you're observing, and maintain an up-to-date observing log for your answers. If you use a recorder, transcribe your observations soon thereafter.

BIG SCOPE CHALLENGE

INTEGRAL SIGN GALAXY (UGC 3697)

Few faint galaxies have names, so when you encounter one, it's usually because an amateur astronomer has identified it as a good object for detailed observation. Such is the case with the Integral Sign Galaxy (UGC 3697) in Camelopardalis. When viewing this magnitude 13.5 spiral, its length-to-width ratio jumps out. UGC 3697 is more than 3' long, but less than 0.3' wide.

{ EQUIPMENT ROUNDUP }

For kids' eyes only

Love of the night sky starts young. Get your child started in astronomy with one of these 14 beginner scopes. /// BY MIKE MARCOTTE

ONE OF THE MOST DIFFICULT questions amateur astronomers are asked to answer is: "What kind of telescope should I buy for my kid?" Usually, the answer not only confuses and disheartens the poor soul who asked the question, but it leaves the astronomer feeling that the 15-minute lecture on telescope optics, computerized mounts, and personal preferences somehow missed the mark.

Here are some pointers to help you find the right telescope to fit the needs and capabilities of your child. For clarity, I consider a child (or kid) to be anybody younger than 15, as those 15 and older should be able to use most telescopes.

ASTRONOMY: KELLIE JAEGER

Understanding the basics

Start by educating yourself on the basics of how a telescope works. The most important aspects to understand are the different types of optical systems — refractors compared to reflectors — and mounts. An Internet search will give you plenty of helpful web sites. One of the best sites I have found is howstuffworks.com. Not only will this site give you a solid understanding of the workings of the telescope itself, filters, and mounts, but it also will provide you with links to books and facts that will help your child enjoy the new instrument.

Next, evaluate your child's needs and capabilities. Be honest: Most children younger than 8 really don't have much interest in viewing celestial objects for more than a moment or two, nor do they have the capability to understand and operate even a basic telescope.

If this describes your child, consider buying a scope that fits your needs and capabilities more than your child's. This way, you'll have an observing tool, and your child can then grow into that telescope. If you decide to do this, keep it simple. Your objective is to teach your kid how to use and enjoy a telescope, and if you purchase a complicated high-end instrument, you are likely to defeat that purpose.

Resources

To find a local astronomy club, go to www.astronomy.com/asy/community/groups.

In the past few years, *Astronomy* has reviewed a number of the telescopes mentioned in this article. See the following issues for those reviews:
Celestron's ExploraScope, February 2005
Orion's StarBlast, January 2004
Orion's SkyQuest, May 2003

Scope specifications

Now you need to determine which kind of telescope will keep your kid's interest instead of overwhelming it. Bear in mind that even the simplest telescopes are precision instruments that must be handled with care. Inevitable adjustments and maintenance might be too hard for some children to manage without adult help or supervision. Consider size, weight, configuration, and ease of operation.

Pay special attention to the telescope's mount. A weak, unsteady mount can make even the best telescope hard to handle. Avoid equatorial mounts, especially those using counterweights, because they may be too complicated and heavy for a child.

Don't forget to research a telescope's eyepieces, too. Most telescopes come with two different size eyepieces, each of which magnifies an object differently. Eyepiece size usually is measured in millimeters — say a 10mm or 20mm eyepiece. The lower the number, the higher the magnification. Magnification is perhaps the most misleading piece of information for novice telescope buyers. This number does not factor in the quality of an instrument — you can buy an eyepiece that promises high magnification, but it may not be well made, so what you see through the scope will be disappointing.

/// QUICK GLANCE

Manufacturer / Model	Type	Weight	Aperture	Computerized	Price
Celestron, www.celestron.com					
ExploraScope	Reflector	5 pounds	3.1 inch (80mm)	No	$60
FirstScope 80AZ	Refractor	18 pounds	3.1 inch (80mm)	No	$250
FirstScope 102AZ	Refractor	18 pounds	4 inch (102mm)	No	$350
Edmund Scientifics, www.scientificsonline.com					
AstroScan	Reflector	11 pounds	4.1 inch (105mm)	No	$200
Meade Instruments Corporation, www.meade.com					
NG60	Refractor	7 pounds	2.4 inch (60mm)	No	$90
NGC60	Refractor	7 pounds	2.4 inch (60mm)	Yes	$200
DS-2070AT	Refractor	12 pounds	2.8 inch (70mm)	Yes	$300
DS-2114ATS	Reflector	16 pounds	4.5 inch (114mm)	Yes	$330
DS-2130ATS	Reflector	18 pounds	5 inch (127mm)	Yes	$400
Orion Telescopes, www.telescope.com					
StarBlast	Reflector	13 pounds	4.5 inch (114mm)	No	$170
SkyQuest XT4.5	Reflector, Dobsonian	18 pounds	4.5 inch (114mm)	No	$200
SkyQuest XT6	Reflector, Dobsonian	35 pounds	6 inch (150mm)	No	$250
SkyQuest XT8	Reflector, Dobsonian	41 pounds	8 inch (203 mm)	No	$350
SkyQuest XT IntelliScopes	Reflector, Dobsonian	18 to 41 pounds	4.5 to 8 inches	Yes	$450 to $600

Another important eyepiece measurement is the barrel size. Avoid telescopes that come with eyepieces or eyepiece holders with a 0.965-inch (2.45cm) barrel diameter because they limit light too much, and this will affect the image. Instead, look for telescopes with at least a 1.25-inch (3.175cm) eyepiece barrel.

Also, you'll need to choose whether you want a computerized telescope, commonly referred to as a go-to scope. As a rule of thumb, I would not recommend a computerized scope for kids younger than 14. In fact, I wouldn't recommend a computerized telescope for anybody who can't go out on a clear night and name the four brightest stars visible at that moment, because even computerized scopes require minimal knowledge of the sky.

The notion that computerized scopes will be easier to operate is a misconception to which many beginners fall prey. Computerized telescopes are easier to use, but they usually must be set up and aligned using a process of steps and information input that will leave most adults — not to mention kids — baffled and frustrated. However, with a little experience and knowledge, a computerized telescope will be a welcome addition to your hobby.

Other factors to consider

In your pursuit of the perfect scope, cost is usually a factor. Putting down a chunk of cash on a telescope that might end up in the closet in a couple of weeks is bad enough, but buying a cheap telescope that is difficult to use can kill your kid's interest on the spot.

The telescope list that follows, although not complete by any means, was compiled with both cost and quality in mind.

Any activity with children, especially astronomy, requires adult participation. Astronomy is more than just looking through a telescope. It is the scientific study of the universe — the motions, positions, sizes, composition, and behavior of celestial objects.

Learning the basics about the celestial bodies you are viewing adds to the enjoyment of having and using a telescope. Many of these concepts are difficult for kids to grasp right away, and your participation can shorten the learning time. It also may help to join a local astronomy club. Most clubs can be found with an Internet search.

Not quite 15 minutes

Please don't run out and purchase the first telescope you see in a department store. Shop around first. With so many high-quality, easy-to-use instruments on the market, finding the ideal first scope should come down to age appropriateness and personal preferences.

What follows are samples of telescopes for kids, but not all the options available from any company. Read over the descriptions to get an idea of the telescopes recommended for each age group. When you find the right scope, your child will look forward to observing objects and also learning about them. A

Mike Marcotte *is a retired firefighter and amateur astronomer who observes from El Paso, Texas.*

Edmund Scientifics

One of the most popular beginner telescopes is the Edmund Scientifics AstroScan. Its unusual "lightbulb" shape won the 1976 Industrial Design Award and quickly became a favorite for kids. The AstroScan has a swivel mount with a 4.1-inch (105mm) reflector telescope and costs $200.

AstroScan
8 to 10 years

Celestron

Celestron offers several telescopes for children. The ExploraScope, a 3.1-inch (80mm) reflector, is a fun and easy-to-use instrument. It uses a sturdy swivel base that can be set on a table or mounted on a photo tripod with the included adapter. Costing around $60 and weighing only 5 pounds, the ExploraScope is a great first telescope for any 8- to 10-year-old. Of course, the rest of the family will enjoy it, too.

For older children, Celestron offers its FirstScope series, a line of refractor telescopes with apertures that range from 2.4 inches (60mm) to 4.5 inches (114mm). Although each member of the series is a fine scope, I recommend either the 80AZ (3.1 inch) or the 102AZ (4 inch). Both scopes offer an altitude-azimuth mount that is more rugged and steady than the one supplied with the 2.4-inch. The 80AZ costs around $250, and the 102AZ is about $350.

SkyQuest XT4.5
10 to 12 years

SkyQuest XT8
12 to 14 years

SkyQuest XT6
12 to 14 years

StarBlast
8 to 10 years

Orion

Orion Telescopes is one of the few manufacturers that make scopes specifically for kids.

Its basic scope is the StarBlast, a reflector that has a 4.5-inch (114mm) mirror and costs $170. It weighs only 13 pounds, is 18 inches long, and is mounted on a simple but sturdy base that is easy for kids to move and use. This is an excellent telescope for an 8- to 10-year-old, but it can be enjoyed by anyone.

A step up from the StarBlast is the SkyQuest XT4.5 dobsonian telescope for $200. It is a reflector also with a 4.5-inch (114mm) mirror and 910mm focal length. Set on one of the sturdiest types of mounts and weighing only 18 pounds, this is one of the best beginner telescopes for 10- to 12-year-olds.

The Orion SkyQuest XT6 is a good scope for those 12 to 14. This is a larger version of the XT4.5, with a 6-inch (150mm) mirror and a 1,200mm focal length. The XT6 weighs 35 pounds, costs $250, and can be a great beginner scope for adults, too.

For 12- to 14-year-olds who are able to control a bigger scope, you might consider the SkyQuest XT8. It costs $350 and weighs 41 pounds. The only difference between the XT6 and the XT8 telescopes is the mirror size — 6 versus 8 inches — and, therefore, the weight.

Orion also offers a line of computerized SkyQuest XT scopes, the SkyQuest XT IntelliScopes. The cost, with the optional Object Locator, is about $250 more than the non-computerized models.

Meade

Meade Instruments Corporation does not make a "kids" telescope, but it has some child-friendly telescopes, starting with its NG60 model. This is a refractor with a 2.4-inch (60mm) lens mounted on an ultra-modern, single-arm design for smooth manual altitude-azimuth motions. This is an excellent starter scope for kids and adults alike.

The computerized NGC60 might be more to the liking of older kids or adults. Once aligned, the NGC60's computer makes it easy to find more than 1,400 sky objects. The NG60 sells for less than $90, and the NGC60 for around $200.

Meade's DS-2000 series is for 12- to 14-year-olds who have a serious interest in astronomy, or may be outgrowing their first telescope. This series includes the DS-2070AT, a 2.8-inch (70mm) refractor; the DS-2114ATS, a 4.5-inch (114mm) reflector; and the DS-2130ATS, a 5-inch (127mm) reflector. These scopes are fully automated and draw on Meade's style 494 Autostar control system with a database of more than 1,500 objects. Expect to pay between $300 and $400 for these telescopes.

DS-2070AT
12 to 14 years

NGC60
12 to 14 years

DS-2130ATS
12 to 14 years

DS-2114ATS
12 to 14 years

NG60
10 to 12 years

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17 must-read books for a cloudy night

When the sky isn't cooperating, nothing satisfies like exploring the universe from the comfort of your armchair. /// BY ROBERT BURNHAM

When night skies cloud over, backyard astronomers move indoors and turn to books. Exploring the universe via the printed page doesn't offer the immediate thrill of peering through an eyepiece — but it will take you places no backyard telescope can. These 17 recent books on astronomy and space, selected by *Astronomy*'s editors, provide great feasts for the mind and eye.

Mark A. Garlick's ***Astronomy: A Visual Guide*** (Firefly Books, 2004) presents the universe for readers new to astronomy, using lots of images. Garlick begins with a chapter on telescopes to start readers with the "how" of astronomy. Chapters then follow on the solar system, stars, and galaxies. A chapter on backyard observing makes a helpful interlude, with monthly sky maps for Northern and Southern Hemisphere viewers. The book ends with sections on cosmology, life in the universe, and a fact-file appendix.

Two excellent encyclopedias appeared in the past year, one using a thematic approach, the other the traditional A–Z. The themed book is the ***National Geographic Encyclopedia of Space***, compiled by Linda K. Glover (National Geographic Society, 2004). The first two sections cover the astronomical universe with essays on topics such as galaxies and asteroids. The remaining sections deal with rocketry, human space flight, Earth-observation satellites (including spy satellites), military uses of space, and more. By including subjects that don't usually appear in the same book, this encyclopedia really does take in all of space, giving much food for thought.

The Firefly Encyclopedia of Astronomy, edited by Paul Murdin and Margaret Penston (Firefly Books, 2004), uses the familiar alphabetical arrangement. Entries range in length from a paragraph to several pages and assume the reader is the interested layman.

Andy Chaikin's coffee-table paperback, ***Space: A History of Space Exploration in Photographs*** (Firefly Books, 2004), will strike baby boomers like a grand tour of the space-time they've lived through. Starting with early rocket pioneer Konstantin Tsiolkovskii, the story progresses through Robert Goddard and Wernher von Braun, to Sputnik (1957) and the start of the space race to the Moon. While unmanned missions to the planets are covered, Chaikin's emphasis lies mostly on manned space flight. The book concludes with Yang Liwei, China's first taikonaut, or astronaut, in 2003.

Two books provide close looks at a pair of famous spacecraft. ***Virtual LM*** by Scott P. Sullivan (Apogee Books, 2004) gives readers a detailed tour of the Apollo lunar module (LM). The accompanying CD-ROM offers the Apollo Operations Handbook and other items, but runs on Windows machines only.

David M. Harland's ***The Story of the Space Shuttle*** (Springer, 2004) gives a detailed history of the shuttle program and International Space Station. Harland takes the story up through the Columbia disaster. A log lists the crews and payloads for each flight, including Columbia's last.

Rockets and spacecraft are built by people with families and personal lives. M. G. Lord's memoir, ***Astro Turf*** (Walker & Company, 2004), is a sensitive look at her parents' lives — her mother abandoned a science career when she married Lord's father. He was an engineer who worked on the Mariner 6 and 7 missions to Mars but

ASTRONOMY: JIM FORBES

was preoccupied by work to the point of estrangement from his family. Lord's exploration of her parents' history and her own also probes gender roles in aerospace engineering and the physical sciences.

For Moon-watchers, the ideal resource is Antonín Rükl's ***Atlas of the Moon*** (Sky Publishing, 2004). The core of the book lies in 76 charts of the Moon's nearside. All craters and many other features are labeled. And for most features, the page facing the map has brief information about the people commemorated, plus crater diameters and depths.

Observing Variable Stars, Novae and Supernovae by Gerald North (Cambridge University Press, 2004) gets backyard astronomers started exploring variable stars. Writing for observers who are no longer raw beginners, North covers telescope adjustments, variable-star types, and estimating brightnesses visually and with CCD cameras. An included CD-ROM (all platforms) contains finder charts, light-curves, and two MPEG movies of variable stars.

Simon Singh's ***Big Bang: The Origin of the Universe*** (4th Estate, 2004) explores how the modern concept for the birth and evolution of the universe arose. Singh's retelling of this story is delightful, as he lucidly describes the science and colorful characters who helped build the theory — sometimes in spite of themselves. It's amusing, for example, to find that Fred Hoyle (who conceived a competing model) gave the Big Bang, in a snort of derision, the very name it's known by.

The search for the distance scale of the universe is a fundamental part of cosmology. In ***Measuring the Cosmos*** (Rutgers University Press, 2004), David H. Clark and Matthew D. H. Clark, father and son, tackle the story. It began with the ancient Greeks, but not until the 20th century could observational astronomy put real numbers to cosmic distances. The Clarks' story ends soon after astronomers discover the mysterious "dark energy" that constitutes most of the universe and is forcing its expansion. What is it? No one knows.

Closer to home, a mystery is unfolding on the little red world next door. Michael Hanlon's ***The Real Mars*** (Carroll & Graf, 2004) is a beautiful and detailed portrait of the Red Planet. The mystery? Whether Mars ever had life. (It's all but certain it doesn't have life now.) Hanlon's text explains how Mars works. He also shows that today's "real Mars" is simply the latest in a series. Every spacecraft we send peels away another layer or two, revealing a more complex, richer, and thereby more real Mars than before.

Finally, Marcia Bartusiak's ***Archives of the Universe*** (Pantheon, 2004) is a collection of translated works of astronomical discovery. Here you'll find Kepler describing planetary motions, Galileo telling about his telescopic findings, William Herschel holding forth on the shape of the universe, and Hans Bethe explaining how stars work. Each of the 75 sections excerpts from papers or books, and each includes an introduction by Bartusiak explaining its significance. This is one cloudy-night astronomy book that puts the discoverers themselves right before you. A

Robert Burnham *is a senior editor of* Astronomy.

/// FOR SPACE CADETS OF ALL AGES

If you have children interested in astronomy — or know of any — ***The Kids Book of the Night Sky*** by Ann Love and Jane Drake (Kids Can Press, 2004) would be an excellent gift. Aimed at 8- to 12-year-olds, it combines an easygoing, hands-on approach to astronomy, encouraging kids to build a red-lens flashlight, start a skywatching notebook, and use a telescope, among other projects. Four seasonal star charts introduce the major constellations, and woven throughout is a lot of basic astronomical knowledge.

Steve Tomecek's ***Moon*** (National Geographic Society, 2005) aims at kids aged 4 to 8. With the help of colorful artwork by Liisa Chauncy Guida, the book leads readers to explore the Moon along with a cat and a firefly. The Moon's birth, cratering, and human exploration are all covered. And for a messy but very grand finale, Tomecek shows how to make a lunar craterscape by dropping pebbles into a pan filled with flour.

Another lunar book (for kids 7 to 10) is ***Neil, Buzz, and Mike Go to the Moon*** by Richard Hilliard (Boyds Mill Press, 2005). It looks at Apollo 11, the first manned landing. Hilliard, both writer and illustrator, follows Neil Armstrong, Edwin "Buzz" Aldrin, and Michael Collins from their childhood dreams of learning to fly airplanes, through astronaut training and early Gemini flights, to the epochal mission of Apollo 11.

For many people, young and old, reading about astronomy often leads to the question of extraterrestrial life. Gloria Skurzynski's ***Are We Alone?*** (National Geographic Society, 2005) is subtitled "Scientists Search for Life in Space." Aimed at readers 8 to 12 years old, the book explores flying saucers, radio searches for ET signals, and deep-sea environments where terrestrial organisms live in extreme conditions. Scattered through the book are vignettes of scientists involved in the search for extraterrestrial life. — *R. B.*

Garlick
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{ GREAT IMAGES }

beautiful universe

A VIBRANT SHELL of gas, the Veil Nebula in Cygnus sprang to life from a star that exploded more than 5,000 years ago. The nebula's western arc, NGC 6960 (top) and NGC 6979 (lower left), challenges observers with small scopes. (4-inch Takahashi FSQ 106 apochromatic refractor at f/5.3, SBIG ST-10XME CCD camera, HαRGB image with exposures of 8, 1, 1, and 1.6 hours, respectively) /// **DANIEL B. PHILLIPS, OCEANSIDE, CALIFORNIA**

INTERESTING FEATURES come and go in Saturn's atmosphere. A single picture won't show these changes, so some amateur astronomers image the planet on a regular basis, occasionally discovering new features. (9¼-inch Celestron Schmidt-Cassegrain telescope at f/39.5, ATK-1HS CCD camera, taken: 1) January 5, 2005, at 00h48m UT; 2) February 7, 2005, at 22h14m UT; 3) February 16, 2005, at 20h30m UT; and 4) February 27, 2005, at 19h35m UT)
/// **DAMIAN PEACH, LOUDWATER, ENGLAND**

1

2

3

4

FEW PLACES are as active as a star's surface. On the Sun, amateur astronomers usually follow developing flares and prominences. Here, a 300,000-mile-long filament shows as a dark "thread." (4-inch Tele Vue TV-102 apochromatic refractor at f/8.6, Coronado SolarMax 90 Hα filter, SBIG ST-2000M CCD camera, taken February 19, 2004, at 17h20m UT)
/// **GREG PIEPOL, ROCKVILLE, MARYLAND**

SLOWLY TWIRLING through Leo, 35 million light-years away, is spiral galaxy M66. The reddish areas are clouds of hydrogen where stars are forming. (12½-inch Parallax Instruments Ritchey-Chrétien telescope at f/9, SBIG ST-10XE CCD camera, LRGB image with exposures of 120, 60, 60, and 60 minutes, respectively)
/// **BOB AND JANICE FERA, CALABASAS, CALIFORNIA**

LIKE THE PALETTE of a cosmic artist, the Rho Ophiuchi region glows in many colors. Antares is the bright star involved in the yellowish nebulosity. To its right, globular cluster M4 glows. The region contains several other emission and reflection nebulae. (12-inch Meade Schmidt Camera at f/2.2, 120-format Kodak Ektar 25 film, combination of two 60-minute exposures) /// **JASON WARE, PLANO, TEXAS**

SIMPLE ASTROPHOTOGRAPHY, such as this star-trail exposure, can yield beautiful results. Remember that long exposures require a dark site. (Tripod-mounted Olympus OM-1 35mm camera, 24mm lens at f/8, Kodak Elite Chrome 100 color slide film, 8-hour exposure) /// **JOE ORMAN, CHANDLER, ARIZONA**

THE ROSETTE NEBULA (NGC 2237–9) lies 5,500 light-years away within the constellation Monoceros. The apparent size of the Rosette is 1° — more than 4 times the area covered by the Full Moon. (6-inch Meade 152ED apochromatic refractor at f/9, 120-format Fuji HG 400 film, combination of two 60-minute exposures) /// **JASON WARE, PLANO, TEXAS**

ANCIENT CULTURES regarded the Pleiades (M45) as a separate constellation. The Greeks often referred to the stars as the "Clusterers." The Pleiades is the closest Messier object, lying 440 light-years away. (4-inch Takahashi FSQ-106 apochromatic refractor at f/8, SBIG STL-11000 CCD camera, LRGB image with exposures of 90, 50, 50, and 50 minutes, respectively) /// **GEORGE GREANEY, LAS VEGAS**

AN OFTEN OVERLOOKED OBJECT, elliptical galaxy M32 lies in the glare of the Andromeda Galaxy (M31). M32 orbits its large companion and lies directly south of M31's nucleus. (8-inch Celestron Schmidt-Cassegrain telescope at f/6.3, Starlight Xpress SXV H9 CCD camera, HαRGB image with exposures of 60, 15, 15, and 15 minutes, respectively)
/// **WOLFGANG PROMPER, GAENSERNDORF, AUSTRIA**

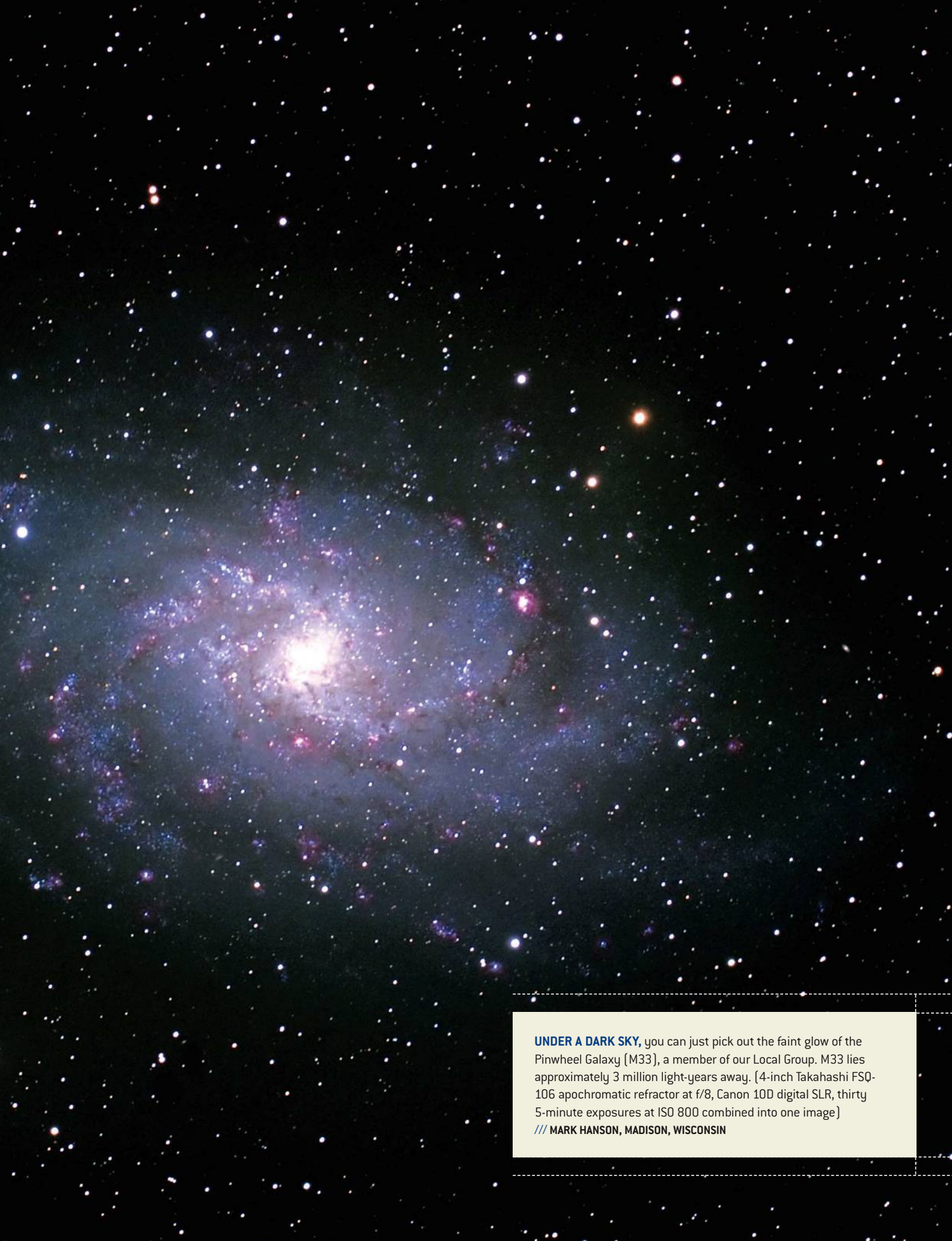
A LUNAR SCAR lies on the border of Mare Nectaris. Theophilus (arrow), a crater 60 miles wide with walls a mile high, was formed long ago by an impact that also left a central peak. (6.2-inch Astro-Physics AP155 StarFire EDFS apochromatic refractor at f/7, SBIG ST-10E CCD camera, $^{1}/_{10}$-second exposure through a green filter, taken March 3, 2002)
/// **DANIEL VERSCHATSE, SAN ESTEBAN, CHILE**

THE DUMBBELL NEBULA (M27) was the first planetary nebula discovered. Charles Messier found it in 1764. Long exposures show the Dumbbell to be nearly half the diameter of the Full Moon. (8-inch Celestron Schmidt-Cassegrain telescope at f/6.3, Starlight Xpress SXV H9 CCD camera, HαRGB image with exposures of 180, 15, 15, and 15 minutes, respectively)
/// **WOLFGANG PROMPER, GAENSERNDORF, AUSTRIA**

SPECTACULAR STAR BIRTH occurs in Orion's "sword," where the Orion Nebula (M42) dominates. Newborn stars provide the energy to make this region glow. Just below M42 is the Running Man Nebula (NGC 1973–75–77). (6-inch Meade 152ED apochromatic refractor at f/9, 120-format Fuji HG 400 film, combination of four 60-minute and one 17-minute exposures) /// **JASON WARE, PLANO, TEXAS**

IN A.D. 1054, A STAR exploded within the boundaries of Taurus the Bull. The resulting supernova remnant — the Crab Nebula (M1) — has been expanding at 3,200,000 mph ever since. (20-inch RC Optical Systems Ritchey-Chrétien telescope, SBIG ST-10XME CCD camera, Astrodon filters, LRGB image with exposures of 90, 56, 56, and 56 minutes, respectively) /// **KEN CRAWFORD, RANCHO DEL SOL CAMINO, CALIFORNIA**

ALONG THE MILKY WAY, open cluster M7 twinkles next to Scorpius' "stinger." It's easy to see M7 with the naked eye from a dark site, but this bright cluster is best seen through large binoculars or a rich-field telescope. (3.2-inch Tele Vue 76 apochromatic refractor at f/6.3, SBIG ST-10XME CCD camera, RGB image wtih 20-minute exposures in red, green, and blue) /// **ALLAN COOK/ADAM BLOCK/NOAO/AURA/NSF, KITT PEAK NATIONAL OBSERVATORY**



UNDER A DARK SKY, you can just pick out the faint glow of the Pinwheel Galaxy (M33), a member of our Local Group. M33 lies approximately 3 million light-years away. (4-inch Takahashi FSQ-106 apochromatic refractor at f/8, Canon 10D digital SLR, thirty 5-minute exposures at ISO 800 combined into one image)
/// **MARK HANSON, MADISON, WISCONSIN**

TWO COSMIC CLOUDS, the Horsehead and Flame nebulae in Orion, demonstrate how different such objects can be. Dark dust makes up the Horsehead (B33), while glowing gas makes up the Flame (NGC 2024). (3.2-inch Orion ED80 apochromatic refractor at f/7.6, Starlight Xpress MX716 CCD camera, LRGB image with exposures of 240, 40, 40, and 40 minutes, respectively) /// **CHUCK DOMARACKI, MEMPHIS, MICHIGAN**

A COTTON BALL through small telescopes, globular cluster M2 in Aquarius resolves into hundreds of pinpoints in large scopes. In all, M2 contains 150,000 stars. You can spot it with your naked eyes from a dark site. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST-10XME CCD camera, LRGB image with exposures of 25, 6, 6, and 6 minutes, respectively) /// **PAT AND CHRIS LEE/ADAM BLOCK/ NOAO/AURA/ NSF, KITT PEAK NATIONAL OBSERVATORY**

THE DOUBLE CLUSTER (NGC 869 AND NGC 884) IN PERSEUS lies near the famous "W" of Cassiopeia the Queen. These clusters were cataloged by the Greek philosopher Hipparchus in 130 B.C. Both clusters lie approximately 7,000 light-years away. (3.2-inch Tele Vue 76 apochromatic refractor at f/6.3, SBIG ST-10XME CCD camera, RGB image wtih 15-minute exposures in red, green, and blue) /// **FRED CALVERT/ADAM BLOCK/NOAO/ AURA/NSF, KITT PEAK NATIONAL OBSERVATORY**

CELEBRATE HALLOWEEN anytime you observe the Witch Head Nebula (IC 2118), which lies near Orion's brightest star, Rigel. The Witch Head is a reflection nebula. It looks blue because this color is most easily scattered, as in our daytime sky. (4-inch Borg 100ED apochromatic refractor at f/4, DTA Chroma CX3 CCD camera, Astrodon filters, LRGB image with exposures of 110, 20, 20, and 20 minutes, respectively) /// **PAOLO CANDY, SORIANO NEL CIMINO, ITALY**

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